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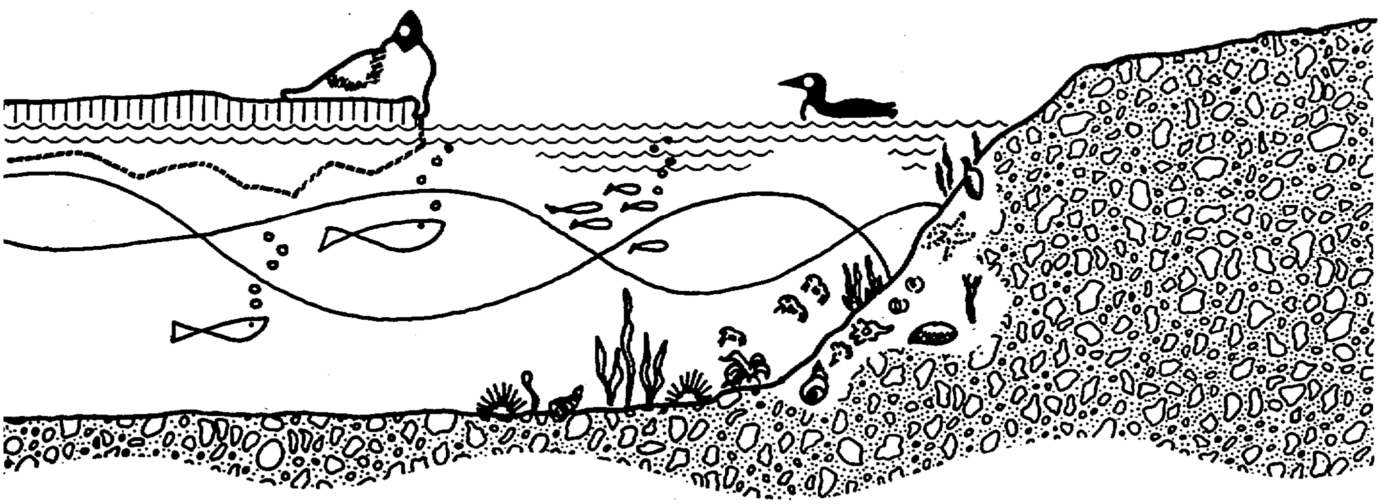
MACROBENTHOS



Baffin Island Oil Spill Project

WORKING REPORT SERIES

1981 STUDY RESULTS

The Baffin Island Oil Spill Project

OBJECTIVES

The Baffin Island Oil Spill (BIOS) Project is a program of research into arctic marine oil spill countermeasures. It consists of two main experiments or studies. The first of these, referred to as the Nearshore Study, was designed to determine if the use of dispersants in the nearshore environment would decrease or increase the impact of spilled oil. The second of the two experiments in the BIOS Project is referred to as the Shoreline Study. It was designed to determine the relative effectiveness of shoreline cleanup countermeasures on arctic beaches.

The project was designed to be four years in length and commenced in 1980.

FUNDING

The BIOS Project is funded and supported by the Canadian Government (Environment Canada: Canadian Coast Guard; Indian and Northern Affairs; Energy, Mines & Resources; and Fisheries & Oceans), by the U.S. Government (Outer Continental Shelf Environmental Assessment Program and U.S. Coast Guard), by the Norwegian Government and by the Petroleum Industry (Canadian Offshore Oil Spill Research Association; BP International [London] and Petro-Canada).

WORKING REPORT SERIES

This report is the result of work performed under the Baffin Island Oil Spill Project. It is undergoing a limited distribution prior to Project completion in order to transfer the information to people working in related research. The report has not undergone rigorous technical review by the BIOS management or technical committees and does not necessarily reflect the views or policies of these groups.

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EFFECTS OF OIL AND DISPERSED OIL ON NEARSHORE MACROBENTHOS AT CAPE HATT, NORTHERN BAFFIN ISLAND.

II. RESULTS OF 1980 and 1981 PRE- AND POST-SPILL STUDIES

by

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July 1982

EXECUTIVE SUMMARY

Effects of experimental spills of oil and dispersed oil on nearshore macrobenthos were studied in four small bays at Cape Hatt, Baffin Island. Lagomedio oil was applied to the surface of one bay on 19 August 1981, and dispersed oil (10 Lagomedio : 1 Corexit 9527) was released underwater in another bay on 27 August 1981. The latter release also resulted in relatively heavy contamination of the third study bay, and low levels of contamination in the surface spill bay and in the fourth (reference) bay.

Systematic sampling was carried out in 3 bays during September 1980 and in 4 bays during August 1981 (pre-spill) and September 1981 (2-4 weeks post-spill). Three transects at each of 2 depths (3 m, 7 m) were sampled in each bay and sampling period. The work on each transect during each study period included (1) collection of eight samples, each covering 0.0625 m^2, using a diver-operated airlift sampler, (2) collection of 8-12 photographs, each covering 0.25 m^2, and (3) *in situ* counts of large organisms and estimates of algal cover within five areas, each 1 x 10 m in dimensions. All fauna ≥1 mm in length were sorted from airlift samples, identified to species where possible, counted and weighed. All bivalves and holothurians were measured, and wet and dry weights were obtained for a subsample of four dominant bivalve species from each bay and period. Photographs and *in situ* counts were used to provide a permanent visual record of the study area and to enumerate large and widely distributed organisms.

In addition to the sampling during the three systematic survey periods, photographs and direct counts of animals at the surface along the standard transects were obtained 2-5 days after the dispersed oil spill. These data provided information about short-term responses to the spill.

Spatial and temporal variability in the benthic community were examined and tested using (1) three-factor (periods, bays, transects) fixed-effects analyses of variance (ANovA), with transects nested within periods and bays, (2) factor analysis and discriminant analysis of community structure, (3) multivariate analyses of variance (MANOVA) to test for changes in community structure, and (4) analysis of covariance (ANCOVA) to examine weight-length relationships. MANOVA and ANCOVA used the same design as ANOVA, and depths were treated separately in all analyses. To test for effects of oil or dispersed oil, we looked for pre- to post-spill changes that occurred in treatment bays but not in the reference bay; the period x bay interaction term in ANOVA, MANOVA and ANCOVA provided a test of significance of oil effects. Variables examined included density and biomass of dominant infaunal taxa, biomass of dominant macroalgal species, density of urchins and starfish, infaunal community structure, and size and weight-length relationships in common bivalve species.

Most of the systematic variability identified by these analyses was spatial and temporal. Nearly all variables differed significantly on small and large spatial scales (among-transects and among-bays, respectively). Significant temporal differences were less common and most often were between 1980 and 1981 rather than between August and September. Year-to-year variability was significant for the abundances of some dominant infaunal taxa and two species of macroalgae, for weight-length relationships in Astarte borealis and Mya truncata, and for infaunal community parameters defined by factor and discriminant analyses. Seasonal (August-September 1981) variability, on the other hand, was significant only for the density of the starfish Leptasterias polaris and (only in the reference bay) for the weight-length relationships of Macoma calcarea.

Oil effects were visually apparent on the first and second days following both spills. Only intertidal amphipods and some larval fish were obviously affected by the 'oil alone' spill. The dispersed oil spill, however, produced marked effects on benthos at both 3 and 7 m depths, and in both the spill bay and the adjacent bay (difference of approximately an order of magnitude in dispersed oil levels). In these bays, a variety of infaunal and epibenthic invertebrates emerged from the substrate and/or assumed unnatural postures (e.g., upside-down); individuals responded slowly or not at all when prodded and many were likely dead.

Oil effects also were detected in sea urchin density data collected 2-5 days after the spill. Urchins apparently moved in response to the dispersed oil spill. Recovery was also apparent in that numbers of urchins present 7-10 days after the spill were returning towards pre-spill levels. An apparent oil effect was also found in the weight-length relationship of the bivalve Macoma calcarea. The only individuals that gained weight between August and September 1981 (pre- and post-spill periods) were smaller individuals in the reference bay.

Unequivocal oil effects on infauna or macroalgae were not detected in the analyses of abundance and biomass data collected 2-4 weeks post-spill. There were some indications of oil effects on a few species or groups (i.e.

the bay x period interaction was significant), but marginal significance levels and inconsistent results from different types of analysis rendered the information doubtful. In some cases with significant bay x period interactions, inspection of the data revealed that the pattern of temporal changes in the various bays was not consistent with the expected pattern if oil effects had occurred. The lack of unequivocal oil effects in abundance and biomass data was probably because of our inability to distinguish between animals that were alive or recently dead when collected. The interval between the spill and the first post-spill sampling was apparently too short for scavengers or decomposes to remove any dead fauna, or for any subsequent changes in community composition to take place. Considering our observations immediately following the dispersed oil spill, however, it is likely that effects on the infaunal community will be detected during 1982. Effects of oil alone would also be expected to increase over time, as the oil is transported to sublittoral sediments.

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INTRODUCTION

The pace of exploration and development of hydrocarbon resources in arctic and subarctic marine areas is likely to increase in the future. Already, exploratory drilling is occurring in the Canadian Beaufort Sea, Sverdrup Basin, Davis Strait and the Labrador Sea, and plans call for offshore drilling in the Alaskan Beaufort Sea, Lancaster Sound and Baffin Bay in the near future. Plans for major offshore oil production are being developed for the Canadian Beaufort Sea, and the Federal Environmental Assessment Review Office is preparing to evaluate the plans. Year-round transport of oil through the Northwest Passage, Baffin Bay and Davis Strait is now a distinct possibility.

Clearly, as the amount of activity increases, the possibility of an accidental release of oil also increases. If oil is released there may be substantial pressure to use chemical dispersants to try to keep the oil from accumulating on the surface of the water or on shorelines.

With or without the use of chemical dispersants, released oil will enter the water column and, especially in nearshore locations, impinge upon the bottom. The initial biological effects will occur among planktonic and benthic invertebrates, although effects at higher levels of the food web may result from the mortality of (or accumulation of oil in) important food species. The use of chemical dispersants may increase biological effects because of dispersant toxicity, increased dissolution of toxic oil fractions, or increased opportunity for the accumulation of oil in sediments.

Recently, considerable attention has been given to the effects of oil and dispersants on individual species of arctic marine flora and fauna under experimental conditions (Percy and Mullin 1975, 1977; Percy 1976, 1977, 1978; Busdosh and Atlas 1977; Malins 1977; Atlas et al. 1978; Foy 1978, 1979; Hsiao et al. 1978), but to date the potential effects on whole communities are unknown. During the recent oil spill investigations following the grounding of the tanker TSESIS in the Baltic Sea, a comparison of approaches towards detecting biological effects supported the 'ecosystem approach' advocated by Mann and Clark (1978): data on reproductive abnormalities in a sensitive species only confirmed effects that were already obvious at the community level (Elmgren et al. 1980). In temperate waters community studies have been carried out for up to 10 years after a spill (e.g. Sanders et al. 1980), but most of these studies have been after the fact; hence they lack adequate 'control' data on pre-spill conditions, on naturally occurring changes that would have occurred in the absence of the spill, or on both (National Academy of Sciences 1975; cf. Bowman 1978). Another shortcoming of many spill studies has been the lack of supporting data on oceanographic and atmospheric conditions, and on hydrocarbon concentrations in the impacted environment (National Academy of Sciences 1975).

To date, no major oil spill has occurred in Canadian arctic waters. In 1978-1979 the Arctic Marine Oil Spill Program (AMOP) examined the need for research associated with experimental oilspills in cold Canadian waters, and thereafter instigated the Baffin Island Oil Spill (BIOS) project to study a controlled introduction of oil and dispersed oil onto shorelines and into nearshore arctic waters. The objectives of this project were to assess the environmental impact of chemical dispersants and the relative effectiveness and impact of other shoreline protection and clean-up techniques. The BIOS project is an internationally funded, multidisciplinary study being carried out by engineers, meteorologists, physical oceanographers, geologists, chemists and biologists from various government departments, industry and research organizations. The nearshore component of the BIOS project includes studies of microbiology and benthic microbiology, atmospheric and oceanographic conditions, and chemical properties of the water column and surface sediments, with special emphasis on concentrations of petroleum hydrocarbons.

The objectives of the microbiological component of the BIOS project are to assess the effects of oil and dispersed oil on the macrophytic algae, the relatively immobile benthic infauna (e.g. bivalves, polychaetes), and the motile epibenthos (e.g. amphipods, urchins) in shallow arctic waters. Variables to be examined include total abundance, total biomass and structure of these communities, as well as the abundance, biomass, population age structure and length-weight relationships of dominant species in these communities. The statistical design of the study is ‘optimal’ for impact assessment (in the sense of Green 1979) in that it includes both temporal (pre-spill) and spatial (unoiled bay) controls.

Cross and Thomson (1981) provided baseline data from three bays at Cape Hatt, Baffin Island (Bays 9, 10 and 11; Fig. 1), during the first of two pre-spill sampling periods (September 1980). In anticipation of the possibility of cross-contamination of the original control bay, a fourth bay remote from the spill site was added to the study design. All four bays were sampled during the second pre-spill sampling period (August 1981). In late August 1981, 15 m3 of untreated Lagomedio oil was released within booms on

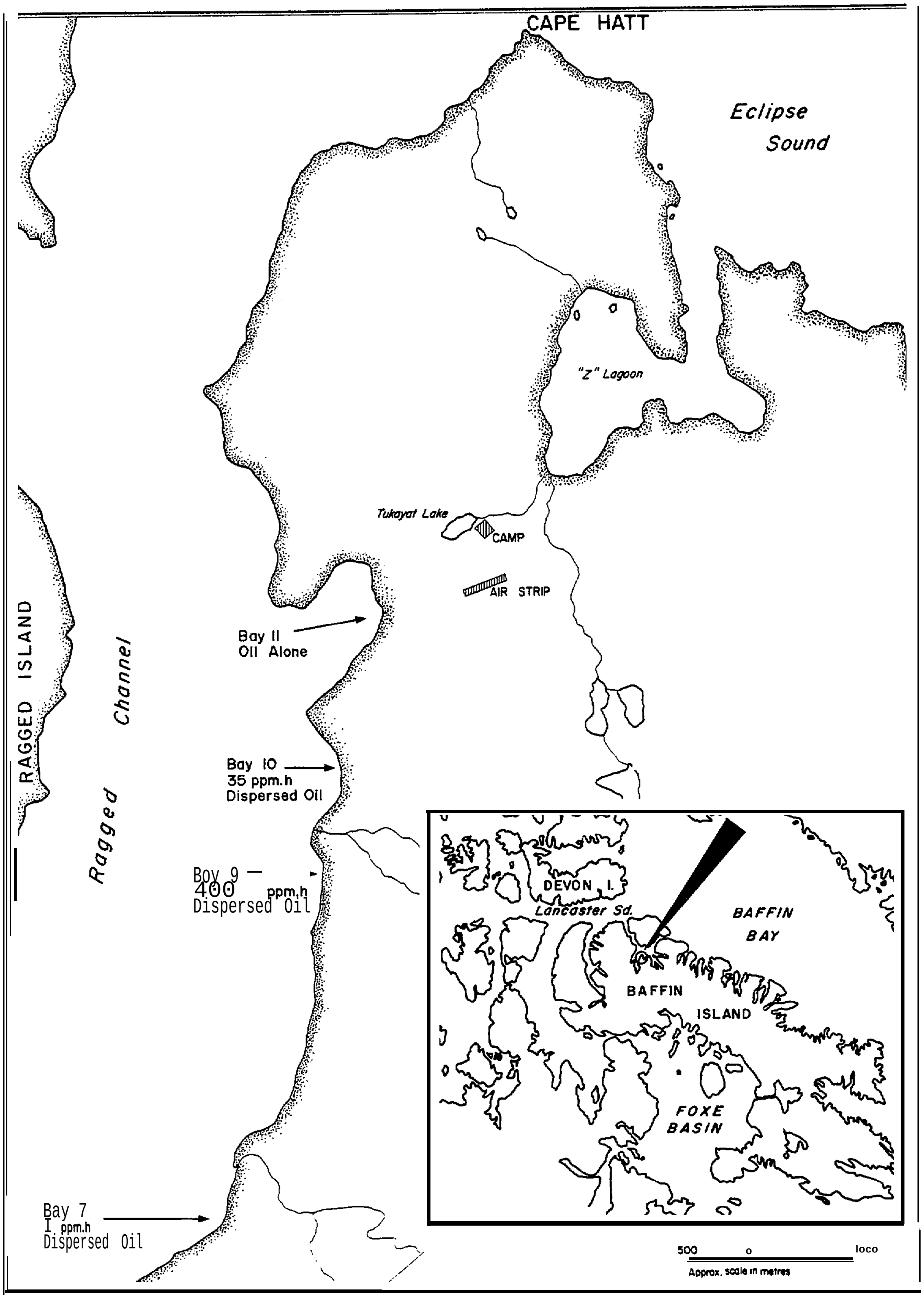

Figure 1. BIOS site at Cape Hatt, Baffin Island, showing the locations of study bays and oil treatments applied in August 1981. Dispersed oil concentrations are maximum estimated exposures in ppm x hours.

the surface of Bay 11, and an additional 15 m3 of the same oil treated with the dispersant Corexit 9527 (10 oil : 1 Corexit) was released underwater in Bay 9 (Fig. 1). Currents carried the dispersed oil into Bay 10, which had originally been designated as the control bay. This resulted in a relatively high level of contamination of Bay 10 -- approximately one order of magnitude lower than that in the oil/dispersant spill bay. For several days following the dispersed oil 'spill' , low levels of oil (average maximum of 50 ppb) were also found in the new control bay--Bay 7--and also throughout Ragged Channel (Fig. 1). The first post-spill sampling was carried out in September 1981 in all four bays.

The present report includes data from 1981 (pre- and post-spill), observations and quantitative data on immediate post- spill effects, and an analysis of oil and dispersed oil effects based on 2 pre-spill sampling periods (September 1980 and August 1981) and one post-spill sampling period (September 1981). The 1980 data are presented in detail in Cross and Thomson (1981). Data from 1980 are repeated here only if directly relevant to the interpretation of oil effects.

METHODS

Study Area

The study area for the nearshore component of the Baffin Island Oil Spill Project consisted of four shallow embayments in Ragged Channel, some 5-8 km SSE of Cape Hatt, Eclipse Sound (72°27'N, 79°51'W). Bays 9 and 10 (dispersed oil bays) are shallow indentations in the coastline, each about 500 m in length, separated by the delta of a small stream and a distance of somewhat less than 500 m. Bay 7 ('control' bay) is similar in size and configuration, located about 6 km to the south, and just south of another small stream. Bay 11 ('oil alone' bay) has been designated as the lower half (and Bay 12 as the upper half) of a deeper embayment approximately 1 km x 1 km in dimensions, located approximately 1 km north of Bay 10 (Fig. 1).

Field Procedures

Observations were made using SCUBA in the study bays during 7 August to 17 September 1980 and 5 August to 20 September 1981. Divers monitored each spill and the condition of each bay on the first day following the dispersed oil spill. Systematic sampling was carried out during 29 August-17 September 1980, 6-17 August 1981 and 29 August-10 September 1981 from the BIOS project camp located at Cape Hatt, Baffin Island (Fig. 1). Additional sampling for other studies continued between the two 1981 periods and until 20 September 1981. All sampling was carried out by divers working from inflatable boats (Zodiacs). Processing and preservation of samples were performed in tents erected on the beach in Bay 12. During September 1980, systematic sampling was carried out in Bays 9, 10, and 11, and during August and September 1981 systematic sampling was carried out in Bays 7, 9, 10 and 11 (Fig. 1).

Sampling Locations

Three contiguous 50 m transects were set parallel to the shoreline at each of two depths in each of the study bays (Fig. 2). A depth of 7 m was selected as the primary sampling depth because of substrate characteristics and time/depth limitations for divers. Transect locations at 7 m depth were chosen in each bay using as criteria (1) similarity in substrate characteristics and infaunal community composition among transects and bays (as determined during preliminary surveys in August 1980 and, for Bay 7, 1981), and (2) facility of sampling (soft substrate with as little surface rock as possible). The second set of three transects in each bay was located immediately inshore of the 7 m transects at a depth of 3 m, where a relatively even cover of algae occurred in each bay.

Transect locations at 3 and 7 m depths were marked underwater during Period 1 (September 1980) by driving steel rods approximately 1 m into the substrate at 50 m intervals along a 150 m line. In each bay, sighting lines at the ends of the transects were established on the shore by placing pairs of markers on the beach. Transects were relocated in Periods 2 and 3 (August and September 1981) using the surface and underwater markers.

A 150 m transect rope marked at 1 m intervals was set between the permanent stakes before (and removed after) sampling at each bay/depth/period combination. Numbered plastic tags attached to the line indicated randomly

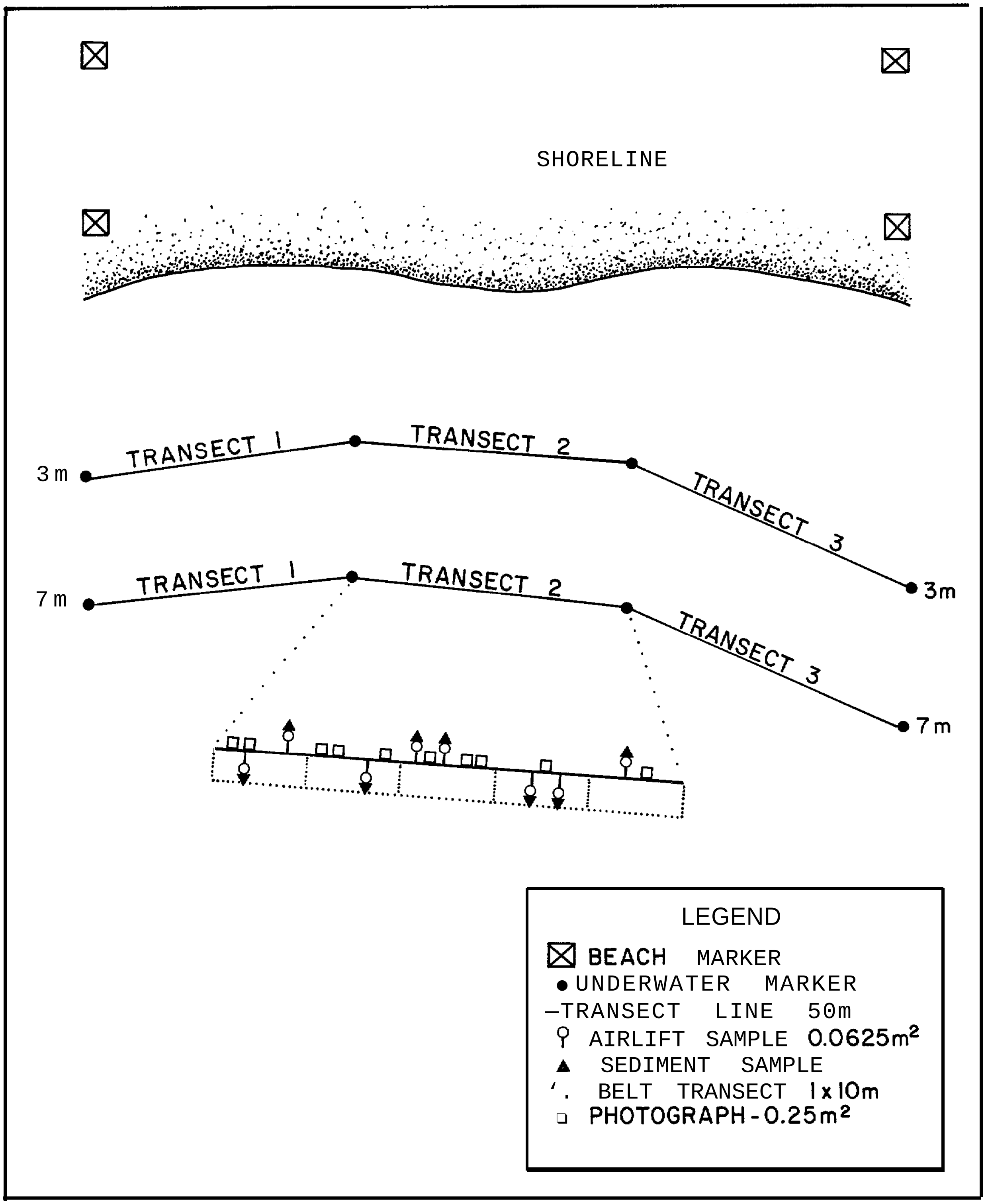

Figure 2. Schematic representation of sampling design for BIOS benthic study. Configuration of transects shown was repeated in each bay, and types and numbers of samples shown for one transect were repeated on each transect at each depth in each bay and period.

selected 1 m2 airlift sampling locations immediately seaward or shoreward of the line; the exact location of the 0.0625 m2 sample within each of these 1 m2 areas was selected to avoid large rocks on the surface of the sediment. Photograph locations along each transect were also randomly selected, and were indicated on a list attached to the camera. Sample locations for airlifts and photographs were re-randomized for each transect and period; on any given transect, randomly selected airlift locations were rejected if they had been used during a previous period. In situ counts and supporting collections were made within 1 x 10 m belts along each transect line.

Airlift Sampling

Infauna were sampled by means of a self-contained diver-operated airlift. Eight replicate samples were obtained on each of three transects at each of two depths in each of three bays in 1980 (total of 144 samples), and in each of four bays in each of two periods in 1981 (total of 384 samples).

The airlift consisted of a weighted 2 m length of pipe 8 cm in diameter fitted at the top with a 1 mm mesh net which retained the sample and could be removed quickly and capped. Air was supplied from a 3000 psi (20 MPa) air cylinder fitted with the first stage of a diving regulator, which reduced air pressure to approximately 125 psi (860 kPa) above ambient. Areas to be sampled were demarcated by a ring containing an area of 0.0625 m2.

The ring was placed on the bottom and pushed as far as possible into the substrate to contain shallow infauna. The airlift was inserted into the ring, the air was turned on, and the mouth of the airlift was moved around to thoroughly cover the area within the ring. The air was turned off when all visible organisms had been collected, and the net on the airlift was then removed, capped and replaced. The depth of penetration of the airlift into the substrate was then measured to the nearest cm, and a sample of surface sediment was taken immediately beside the excavated area. After 3 or 4 samples had been taken they were raised to the boat and rinsed in the collecting bags from the side of the boat in order to remove fine sediments, Immediately after each dive all samples were returned to the field laboratory.

Quantitative Photography

A photographic record of each transect during each period was obtained on colour slide film using a Nikonos camera with a 15 mm lens, paired Vivitar electronic flashes and a fixed focus framer covering a bottom area of approximately 0.25 m2. Ten photographs were taken at randomly located intervals along each 50-m transect line during each of Periods 1, 2 and 3. In addition to providing a permanent visual record of each study area, photographs were used to estimate densities of visible surface fauna that were too sparsely distributed to be represented adequately in airlift samples. In order to obtain quantitative information on effects that were apparent immediately after the dispersed oil spill, an additiona" six randomly located photographs were taken on each transect in Bays 9 and 10 on the second post-spill day. Photographs were also taken in Bays 7 and 11 on the fourth and fifth post-spill days. (No immediate effects were apparent in these bays.)

In Situ Counts

Macro phytes and those invertebrates too large and sparsely distributed to be representatively sampled by airlift or camera were counted in situ. On each transect during each period, counts of urchins, starfish and individual kelp plants, as well as estimates of percent bottom cover by algae, were made within five 1 x 10 m strips parallel to and immediately adjacent to the transect line. Collections of representative plants and animals were also made for species identification. Additional counts of urchins and starfish were made after the dispersed oil spill using both in situ and photographic techniques (see above).

Laboratory Analysis Procedures

All samples were processed in the field within 12 h of collection. Samples were emptied into large plastic trays, and nets were carefully rinsed and picked clean. Entire samples (minus large rocks and gravel) were labeled and preserved in 10% formalin. Macrophytic algae other than those in airlift samples were pressed on herbarium paper and dried at room temperature.

Detailed laboratory processing and analysis of samples was carried out within six months of collection. Samples were initially rinsed to remove formalin and sediment, and then separated into five fractions: (1) All material passing through a 1 mm mesh screen and retained on a 0.45 mm mesh screen was preserved in alcohol for future reference. (2) A 'floating' fraction, separated by rinsing, contained algae, detritus and most soft bodied animals. This fraction was examined under a binocular microscope and animals $\geq$1 mm in length were sorted into major taxonomic groups; the remaining algae and detritus was blotted dry and weighed on a Mettler PT 200 balance. In 18 of the 528 samples that contained large volumes of algae (>1000 mL), large and conspicuous organisms were picked from the entire sample but only a subsample of known weight was examined microscopically. (Fractions 3-5) Nested seives were used to separate the balance of the sample into three different size fractions (l-2.8 mm; 2.8-5.6 mm; $\geq$5.6 mm) containing sand, gravel, bivalves and some soft bodied animals. Each fraction was sorted separately in glass trays into major taxonomic groups. Shell fragments from the largest size fraction and entire bivalve shells from each fraction were separated, labeled and stored for future reference.

During 1981, several unsorted samples were inadvertently mixed during laboratory analysis. In one case, two samples from different depths (3 m and 7 m, Bay 10, Period 2) were mixed; these were not analyzed. In two cases, two samples from the same transect were mixed: 3 m and 7 m in Bay 11 during Period 3. In these two cases the two samples were combined, processed, and the results divided by two to provide data on one 'composite' sample. The resultant loss in data was, therefore, one of eight replicates at each of 3 m and 7 m in Bay 10 during Period 2, and at each of 3 m and 7 m in Bay 11 during Period 3.

All animals were identified to species level whenever possible; unidentified or tentatively identified species were sent to appropriate authorities for identification or verification (see Acknowledgements) . For each taxon identified, individuals were counted, gently blotted dry, and weighed together to the nearest milligram on a Mettler PT 200 balance. Unless otherwise specified (see below), all weights presented in this report are preserved (10% formal in) wet weights, including mollusc shells but excluding polychaete tubes. Lengths of individuals of all bivalve species, and diameters of the calcareous oral rings of the holothurian Myriotrochus rinkii, were measured to the nearest millimetre. After laboratory examination, all taxa were stored in 75% ethanol; a solution of 3% propylene glycol in 75% ethanol was used for crustaceans,

For each of four common bivalve species (Mya truncata, Astarte borealis, Macoma calcarea, and Serripes groenlandicus), the relationships between length, wet weight and dry weight were derived as follows: For each bay and period, approximately fifty undamaged individuals of each species were selected (where possible) from airlift samples taken along the middle transect at 7 m depth; S. groenlandicus was selected only from 1981 samples. If necessary to obtain a sample size of 50 per bay, animals from the inner ends of the outer two 7 m transects were also used, For each individual the length, wet weight including shell, wet meat weight, and dry (constant) meat weight were determined. Constant dry weight was obtained by drying at 60°C in a Fisher Isotemp Oven Model 301 and weighing at daily intervals until constant weight was found.

Airlift samples of algae and detritus from 3 m depths were weighed (see below) , and 213 of the 262 samples from 3 m were analyzed in detail. Large and conspicuous species were sorted from each of these samples and weighed; in three cases (samples that had been subsampled for invertebrate sorting), only the subsample was examined. A subsample of approximately 2 g wet weight was separated from the balance of the sample, and sorted completely into the following categories: Stictyosiphon tortilis, Dictyosiphon foeniculaceus, *Sphacelaria* spp., a mixture of *Pilayella littorals* and tubular diatoms, other species, and detritus (non-algal material). An appropriate subsample factor was then applied to extrapolate these results to the unsorted portion of the sample. Formalin wet weights were determined by rinsing in water, removing water by vacuum filtration in a Buchner funnel using Whatman #1 Qualitative filter paper until drops were 30 seconds apart, and weighing immediately to the nearest milligram on a Mettler PT 200 balance.

Data Processing and Analysis

All quantitative data collected in the field and all results from laboratory analyses were coded for computer processing. Computer programs developed by LGL were used to generate the sample by sample, transect by transect, and bay by bay tabulations that were used to select species and taxa for further analyses. Other LGL programs were used to organize the data into a format acceptable to packaged statistical programs. Prior to analyses a logarithmic transformation (log [x+1]) was applied to density and biomass data in order to reduce the skewness inherent in such data. Many of the analyses conducted on 1980 data (Cross and Thomson 1981) showed significant bay by depth interactions, so separate analyses were run on data from each depth, both for 1980 data and in the present report.

Three-factor (periods, bays and transects) fixed-effects analyses of variance, with transects nested within periods and bays, were used to examine and test spatial and temporal variability in the benthic community. Per iod (temporal) effects included both seasonal (August/September) and yearly (1980/1981) components. Because of the nested design, the transect term rather than the residual error term was used to test the significance of main effects (periods, bays) and of the interaction between the main effects. When interaction terms involving transects were non significant ($P>0.05$), they were pooled with the transect term before we tested for main effects. When interactions involving transects were significant ($P\leq0.05$), they were not pooled with the transect term. Analyses of variance were performed separately for each depth by the GLM procedure of the SAS computer program package (Helwig and Council 1979; Freund and Littell 1981).

The unbalanced design that resulted from the addition of the fourth bay in 1981 necessitated the use of two separate types of analysis to test for oil effects whenever analysis of variance (ANOVA) or multivariate analysis of variance (MANOVA--see below) were used. One analysis, hereafter referred to as 3 bay/3 period, included data from all three periods and only the three bays sampled in all periods (Bays 9, 10 and 11). The other analysis, hereafter referred to as 4 bay/2 period, included data from all four bays and only the two periods during which all bays were sampled (Periods 2 and 3). Additional analyses were carried out to test for seasonal variation in the reference bay (Bay 7) during Periods 2 and 3 (August and September 1981).

Factor analysis (BMDP; Dixon and Brown 1981) was used to identify recurring groups of species. The principal components method was used to extract initial factors from the correlation matrix of log-transformed species abundance data. Final factors were generated by varimax rotation. Separate factor analyses were performed on dominant species from each depth. The scoring coefficients produced by this analysis were applied to log-transformed species abundances to produce factor scores for all samples collected during all sampling periods.

These factor scores were used as dependent variables in multivariate analyses of variance (SAS general linear models program; Helwig and Council 1979). Depths were treated separately and the three-way design (periods, bays, transects nested within bays and periods) employed in univariate ANOVAS was used. Transect effects were used to test main effects, as above. An *a priori* decision was made to use Pillai's trace as the test of significance in MANOVA. The elements of the vectors produced in MANOVA were applied to the factor scores to derive discriminant functions. Group centroids were plotted against the discriminant functions for each test of main effects and interaction.

The functional relationships between lengths and weights of dominant bivalve species were identified by analysis of (1) scatter plots of the 1980 data, and (2) plots of residuals generated by regression analyses (Cross and Thomson 1981). The type of relationship determined the type of transformation used in subsequent analyses. Analyses of covariance (ANCOVA) with the corresponding function of length as the covariate were used to test for differences in dry meat weight among periods and bays, using both 1980 and 1981 data. ANCOVA was carried out using the SAS GLM procedure (Helwig and Council 1979).

The mean lengths of selected bivalve species were calculated for each sample and analyses of variance were used to test whether mean lengths of these species differed among bays or periods.

RESULTS AND DISCUSSION

The benthos in the study bays at Cape Hatt consists of a wide variety of animals which, for the purposes of the present study, have been classified into two groups according to their relative mobility. The term infauna will be used to refer to those animals that are either incapable of motion or are able to move only slowly in the sediment or on the sediment surface. This group includes bivalves, polychaetes, gastropod, priapulids, nemerteans and some echinoderms. The term epibenthos will be used for those animals capable of relatively rapid motion, including amphipods, cumaceans and ostracods, and large echinoderms capable of mov ing relatively large distances on the sediment surface (urchins and starfish). Both of these groups (infauna and epibenthos) are included in the infauna as defined by Thorson (1957).

The infauna and epibenthos (as defined above) will be treated separately in the present study. Most analysis and discussion will concern infauna, primarily because their relative immobility will expose them to the full impact of oil or dispersed oil and facilitate the interpretation of results. With mobile epibenthos, it is often impossible to distinguish between mortality and emigration as the cause of disappearance following an oilspill (e.g. Elmgren et al. 1980). Infauna are also of interest because of their dominance of total benthic biomass (99.4% in the study bays at Cape Hatt), and because of their long life spans in the Arctic (Curtis 1977; Petersen 1978). The latter further facilitates interpretation of results because it is indicative of comparatively reduced seasonal and annual variability.

The design of this study incorporates several potential sources of variability besides any effects of oil or dispersed oil. These include water depth, spatial variability on three scales (within transects, among transects within bays, among bays), and temporal variability between seasons and years. It is important to examine the effects of each of these sources of potential variability in order to differentiate their effects from those of oil or dispersed oil.

The effect of depth (3 m vs. 7 m) was assessed in the first year of studies (Cross and Thomson 1981). Significant between-depth differences in infaunal communities were found. Furthermore, these differences between depths were not consistent among the three bays studied. The latter effect (an interaction effect in statistical terms) was itself indicative of a depth effect, but for statistical reasons the significant interaction precluded unambiguous interpretation of depth or bay effects themselves. The addition of a temporal effect after the second year of studies increases the number of possible interactions involving depth (depth x bay; depth x period; depth x period x bay), thereby rendering interpretation of any effect practically impossible. Thus, separate analyses were used for data from each depth throughout the present report, thereby eliminating all of the interaction terms involving depth from the analyses.

Spatial variability is fundamental to the study design. The smallest-scale variability, that among replicate samples within transects, is used as a basis of comparison for variation among transects. Among-transect variation, in turn, is used to determine the significance of variation among bays. This among-bay variation is one of the main effects we are testing;

differences among bays, however, could be attributable either to natural factors or to the different oil treatments applied in the different bays. An additional factor (time) is required in order to differentiate between oil effects and natural spatial variability.

The temporal variability assessed in the BIOS project, termed the period effect, includes both seasonal and year-to-year components, Sampling is being carried out in both August and September, and in different years. At the end of the four year study it will be possible to separate the period effect into its seasonal and annual components in the analyses of variance; this will be possible because, at the end of the study, a balanced design will have been achieved (3 August samplings, in 1981, 1982, 1983; and 3 September samplings in 1980, 1981 and 1982). At present, there have been two sampling periods in September (1980, 1981) but only one in August (1981). Thus, we currently have only one temporal factor representing the three sampling periods to date.

Oil effects will be determined by comparing temporal changes in the experimental (spill) bays with temporal changes in the reference bay; in statistical terms, a significant interaction between bay and period effects will indicate an oil effect. At the end of the experiment these tests will be based on data from sampling periods ranging from one year pre-spill to two years post-spill. The analyses outlined in the present interim report include data collected between September 1980 (1 year pre-spill) and September 1981 (2-4 weeks post-spill).

In fauna

Sampling Efficiency

Cross and Thomson (1981) reported that the penetration depth and the total area sampled by the airlift in each of Bays 9, 10 and 11 appeared to be sufficient to yield samples that adequately represent the types and quantities of animals present. This was based on *in situ* inspection of the sampling plots, and on species-area curves derived from 1980 data at each depth in each bay. Particular care was taken during sampling to collect all individuals of the deeply burrowing bivalve *Mya truncata*.

Group and Species Composition

Group composition of the infauna collected in the study area at Cape Hatt in the three sampling periods (bays and depths combined) is shown in Table 1. Bivalves accounted for most of the biomass (87.2 to 93.3%); bivalves and polychaetes, in approximately equal proportions, accounted for most of the numbers of animals collected (83.1 to 85.6%).

The most common animals taken from samples at Cape Hatt in each period are shown in Tables 2 and 3, and a complete species list is included in Appendix 2. Twelve species accounted for 88.8 to 93.1% of the infaunal biomass (Table 2), and a partially overlapping list of 12 taxa accounted for 65.4 to 65.6 % of the numbers of animals collected (Table 3). Only four species were dominant (i.e. among the top 12 species) in terms of both biomass and density: the bivalves *Mya truncata, Astarte borealis, Astarte montagui* and *Macoma calcarea*.

Table 1. Group composition of infauna collected in the study bays at Cape Hatt, northern Baffin Island, during September 1980 and August and September 1981[1]. Based on 524 samples, each covering 0.0625 m^2, from 3 and 7 m depths.

Taxon	% of total numbers			% of total biomass (wet weight)		
	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3
Bivalvia	45.34	41.97	40.96	93.25	87.15	90.29
Polychaeta	40.25	42.71	42.09	3.74	4.87	3.81
Gastropoda	8.26	10.06	10.99	1.14	1.24	1.39
Echinoidea	0.04	0.09	0.05	0.98	3.88	2.54
Holothuroidea	4.02	3.21	3.54	0.36	0.43	0.51
Ophiuroidea	0.06	0.14	0.12	0.15	0.51	0.28
Asteroidea	0.77	0.18	0.15	0.05	0.81	0.04
Ascidiacea	0.08	0.02	0.01	0.02	0.002	0
Other	1.18	1.62	2.09	0.30	1.10	1.14
Total infauna	2906.3 (ind./m^2)	2381.2 (ind./m^2)	2557.9 (ind./m^2)	1172.6 (g/m^2)	829.6 (g/m^2)	855.1 (g/m^2)

[1] Period 1 = pre-spill, September 1980; Period 2 = pre-spill, August 1981; Period 3 = post-spill, September 1981.

Table 2. Percent contribution to total in faunal biomass (wet weight) by dominant species in the study bays at Cape Hatt, northern Baffin Island, during September 1980 and August and September 1981[1]. Based on 524 samples, each covering 0.0625 m^2, from 3 and 7 m depths.

Dominant species	% of total infaunal biomass		
	Period 1	Period 2	Period 3
Mya truncata (B)	50.83	39.23	44.81
Astarte borealis (B)	18.38	19.06	18.97
Serripes groenlandicus (B)	8.42	9.84	6.82
Astarte montagui (B)	4.41	5.40	5.73
Hiatella arctica (B)	2.87	2.49	1.75
Macoma calcarea (B)	2.86	4.26	4.14
Cistenides granulata (P)	1.10	1.39	1.13
Strongylocentrotus droebachiensis (E)	0.98	3.89	2.54
Musculus niger (B)	0.91	0.78	1.01
Musculus discors (B)	0.87	0.72	0.87
Macoma moesta (B)	0.84	1.08	1.19
Trichotropis borealis (G)	0.64	0.67	0.77
Total % contribution	93.11	88.81	89.73
Biomass of all infauna (g/m^2)	1172.6	829.6	855.1

B = bivalve, P = polychaete, G = gastropod, E = echinoid.

[1] Period 1 = pre-spill, September 1980; Period 2 = pre-spill, August 1981; Period 3 = post-spill, September 1981.

Table 3. Percent contribution to total infaunal numbers by dominant species in the study bays at Cape Hatt, northern Baffin Island, during September 1980 and August and September 1981[1]. Based on 524 samples, each covering 0.0625 m^2, from 3 and 7 m depths.

Dominant species	% of total infaunal numbers		
	Period 1	Period 2	Period 3
Pholoe minuta (P)	11.84	15.25	15.78
Thyasiridae sp. (B)	8.29	8.77	8.91
Astarte borealis (B)	8.13	9.21	8.55
Nereimyra punctata (P)	6.86	6.32	5.01
Mya truncata (B)	6.13	4.87	4,33
Astarte montagui (B)	5.10	5.98	6.11
Astarte sp. juveniles (B)	4.23	1.15	1.11
Myriotrochus rinkii (H)	4.02	3.21	3.54
Euchone analis (P)	3.81	2.85	3.80
Chaetozone setosa (P)	2.80	0.73	1.08
Cingula castanea (G)	2.22	3.67	4.16
Macoma calcarea (B)	2.20	3.36	3.18
Total % contribution	65.63	65.37	65.56
Density of all infauna (no./m^2)	2906.3	2381.2	2557.9

B = bivalve, P = polychaete, G = gastropod, H = holothurian.
[1] Period 1 = pre-spill, September 1980; Period 2 = pre-spill, August 1981; Period 3 = post-spill, September 1981.

In general, the benthos of the study area at Cape Hatt appears to be typical of that in other nearshore high arctic areas. Several of the dominant infaunal species, including several of those contributing most to biomass (Mya truncata, Macoma calcarea, M. moesta, Astarte borealis, A. montagui, Serripes groenlandicus, and Cistenides granulate), belong to the arctic Macoma community (Thorson 1957; Ockelmann 1958; Ellis 1960; Thomson 1982). This community is a widespread and common feature of nearshore high arctic areas and is displaced only under local circumstances (e.g. under estuarine influences). A quantitative analysis of community structure in the study bays is presented in a following section.

Biomass

Average infaunal biomass in the study area at Cape Hatt (all bays and depths considered) was from 830 to 1171 g/m2, depending on period (Table 2). At 3 m depth, mean biomass was 328 - 492 g/m2; at 7 m it was 1292 - 2017 g/m2. These values are considerably higher than mean depth-integrated (5 to 50 m) biomass in other arctic areas:

Location*	Sample size	Mean biomass (g/m2)	Source
Alaskan Beaufort Sea	131	41	Carey (1977)
Bridport Inlet, Melville Is.	78	94	Buchanan et al. (1977)
Brentford Bay, Boothia Pen.	21	188	Thomson et al. (1978)
Lancaster Sound	110	319	Thomson and Cross (1980)
Pond Inlet and Arctic Bay	51	200-438	Ellis (1960)

* Relatively high biomass (up to 1482 g/m2 at one location, n = 7) has also been reported in West Greenland (Vibe 1939).

The apparently high in faunal biomass at Cape Hatt relative to that in other arctic locations is likely due largely to the effectiveness of our sampler. About half of the biomass found at 7 m depth at Cape Hatt represented Mya truncata. Cross and Thomson (1981) found that this deeply burrowing species was only sampled effectively if the sediment was excavated to a depth of 15 cm. Buchanan et al. (1977) compared results of quantitative underwater photographs with those of shallow penetrating samplers and found that their shallow samples underestimated infaunal biomass by as much as 960 g/m^2. Many of the other low values previously reported may also be biased by inadequate sampling.

In most high arctic areas a barren zone extends from the shoreline to depths of 2 to 10 m. This zone is devoid of infauna except for the tunicate Rhizomolgula globularis, and is populated almost exclusively by motile amphipods. At Cape Hatt, however, a relatively high infaunal biomass consisting mainly of bivalves was found at 3 m depth. Here and elsewhere in Eclipse Sound the barren zone occurs only at shallower depths, likely due to the relatively protected location (Thomson and Cross 1980).

Factors Affecting Abundance and Biomass

Mean density ($no./m^2$) and biomass (g/m^2) of bivalves, polychaetes, total infauna and species that are dominant either in terms of density or biomass are given in Tables 4 and 5. Considerable spatial and temporal variability is evident for most groups and species; spatial variability is evident both within and among bays, and between depths. The smallest scale of variability detectable with our study design is that among replicate samples within

Table 4. Mean density (no./m2) of major taxa and selected species of infauna in four bays[1] at Cape Hatt, northern Baffin Island, during September 1980 and August and September 1981[2]. Data are expressed as mean ± standard deviation and are based on 8 replicate 0.0625 m2 airlift samples m each of three transects for each depth, period and bay.

Taxon	Period	3 m Depth				7 m Depth			
		Bay 7	Bay 9	Bay 10	Bay· 11	Pay 7	Bay 9	Bay 10	8ay 11
Total infauna[3]	1		3765.3 ± 1005.1	3013.3 ± 1025.2	1486.0 * 860.4		3580.7 ± 1312.9	2840.7 ± 852.1	2752.0 ± 631.0
	2	15%.7 ± 816.8	3690.0 ± 1649.6	2261.9 ± 777.3	1033.8 ± 505.2	2285.3 ± 758.0	3092.0 * 959.7	2177.4 ± 5%.6	2849.3 ± 1415.3
	3	1838.0 * 912.5	4326.7 ± 2093.4	2487.5 ± 835.1	1311.4 * 649.0	2472.0 ± 597.6	29%.0 ± 762.7	2581.1 * 659.5	2391.6 ± 9$9.8
Polychaeta	1		1879.3 ± 568.7	1598.7 ± 541.7	877.3 ± 501.6		880.0 * 329.7	%0.0 ± 326.6	842.7 ± 271.7
	2	800.7 ± 487.7	1818.7 ± 834.0	1415.0 ± 523.0	724.4 * 359.1	727.3 * 293.0	922.7 ± 371.9	742.3 * 280.3	990.7 ± 631.6
	3	992.0 * 593.1	1888.0 ± 793.0	1412.7 ± 542.1	831.1 ± 438.1	758.0 ± 275.1	953.3 * 288.0	1100.9 * 475.7	647.6 ± 254.7
ivalvia	1		1103.3 ± 604.4	907.3 * 568,9	303.3 * 284.1		2284.0 ± 808.4	1726.7 * 686.9	1582.() ± 498.8
	2	254.7 ± 194.8	1126.7 ± 777.8	532.5 ± 225.1	148.2 ± 1%.3	1216.7 ± 640.3	1896.7 * 622.8	1261.9 * 550.0	1550.0 ± 743.4
	3	238.7 * 190.5	1384.0 ± 960.0	591.8 ± 300.4	208.9 ± 230.0	1408.0 * 554.9	1797.3 * 568.4	1302.7 ± 531.5	1432.0 ± 641.0
Mya truncate	1		282.7 * 159.1	225.3 * 211.9	57.3 * 57.8		176.0 * 83.3	152.7 ± 97.2	176.0 ± 87.8
	2	52.0 ± 45.6	241.3 ± 149.2	119.0 ± 75,8	25.3 ± 43.7	96.0 ± 58.4	109.3 * 67.2	98.8 ± 131.3	184.7 * 118.3
	3	66.0 * 55.1	266.7 ± 181.2	108.7 ± 64.3	27.8 * 49.5	101.3 * 57.5	86.7 * 48.6	89.3 * 43.5	137.7 * 70.2
Astarte borealis	1		193.3 ± 154.0	57.3 * 90.9	20.0 ± 30.3		424.0 * 266.6	353.3 ± 223.2	359.3 ± 198.0
	2	66.7 ± 66.7	306.0 ± 281.3	80.5 ± 76.6	30.0 * 57.6	160.0 * 126.2	320.7 ± 177.6	329.0 ± 184.7	460.0 * 224.3
	3	64.7 ± 83.3	298.0 ± 235.0	141.3 ± 122.1	9.7 ± 13.4	202.7 * 116.6	336.0 ± 205.3	292.0 * 135.9	404.5 ●237.5
Astarte montagui	1		136.7 * 173.8	5.3 ± 23,0	2.0 * 7.2		178.7 ± 153.4	140.7 * 101.4	426.0 * 261.0
	2	15.3 ± 37.6	222.7 ± 207.6	23.7 ± 42.6	8.0 ± 35.7	43.3 ± 47.8	141.3 ± 99.3	174.6 ± 146.4	507.3 ± 2%.1
	3	13.3 ± 28.6	308.0 ± 303.8	27.3 ± 48.7	2.1 ± 7.3	45.3 ± 39.1	146.0 ± 103.3	219.3 ± 180.6	495.7 ± 312.5
Thyasiridae	1	-	220.7 ± 241.1	124.7 ± 99.9	8.0 ± 20.6		590.0 * 235.3	433.3 ± 238.8	69.3 ± 79.2
	2	18.0 ± 29.2	178.0 ± 157.4	77.1 ± 62.1	1.3 ± 4.5	345.3 * 233.1	612.7 ± 226.0	365.9 ± 228.4	74.0 ± 78.2
	3	30.0 ± 39.0	253.3 ± 363.2	110.0 ± 74.5	9.7 ± 30.8	414.7 ± 219.9	541.3 ± 201.5	368.0 ± 225.0	80.0 ± 144.4
Euchone analis	1		428.0 ± 491.0	139.3 ± 135.9	79.3 * 95.7		4.0 * 13,6	6.0 * 14.8	8.0 ± 21.6
	2	58.0 ± 61.8	319.3 ± 264.0	105.7 * 73.3	22.0 ± 42.2	6.7 ± 15.6	9.3 ± 17.0	14.6 * 27.7	6.7 ± 11.5
	3	140,7 ± 177.5	412.7 ± 304.6	164.0 * 161.3	20.2 ± 31.3	6.7 ± 10.5	18.7 * 29,0	7.3 * 16.3	0.7 * 3.3
Myriotrochus rinkii	1		350.0 ± 175.5	142.0 ± 139.4	92.0 ± 79.4		90.7 * 100.5	0.7 ± 3.3	26.0 ± 65.9
	2	102.0 * 10$.6	273.3 ± 158.3	76.4 ± 57.2	90.7 * 81.8	23.3 * 53.4	30.7 ± 40.3	7.7 * 26.8	4.0 * 14.3
	3	110.7 ± 103.0	266.7 ± 133.8	143.8 * 122.9	120.8 ± 150.0	4.7 * 17.3	62.7 ± 82.7	1.3 * 4.5	11.1 * 31.1
Capitella capitata	1		54.0 * 157.4	39.3 ●37.4	20.0 ± 26.8		14.0 ± 23.3	27.3 ± 52.6	11.3 * 14.5
	2	29.3 * 37.9	33.3 * 56.6	54.2 ± 68.3	17.0 * 25.1	19.3 * 27.1	14.7 ± 36.8	9.0 * 11.6	22.0 * 33.6
	3	20.7 ± 30.8	17.3 ± 32.0	41.3 ± 74.1	9.0 ± 12.6	10.0 * 14.8	8.7 ± 12.5	16.7 * 22.4	7.0 * 10.6

1 Bay 7 = reference; Bay 9 = heavy dispersed oil; Bay 10 = light dispersed oil; Bay 11 = surface oil spill.
2 Period 1 = pre-spill, September 1980; Period 2 = pre-spill, August 1981; Period 3 = pst-spill, September 1981.
3 All taxa but ostracods, cumaceans and amphipods.

Table 5. Mean biomass (g/a?) of major taxa and dominant species of infauna in four bays[1] at Cape Hatt, northern Baffin Island, during September 1980 and August and September 1981[2]. Data are expressed as mean ± standard deviation and are basal on 10% formalin wet weight in 8 replicate 0.0625 m^2 airlift samples on each of three transects for each depth, period and bay.

Taxon	Period	3 m Depth				7 m Depth			
		Bay 7	Bay 9	Bay 10	Bay 11	Bay 7	Bay 9	Bay 10	Bay 11
Total infauna[3]	1		595.9 ± 414.2	304.2 ± 222.3	83.3 ± 109.8		2844.0 ± 1112.4	1602.2 ± 767.2	1606.1 ± 853.3
	2	176.9 * 176.6	675.9 * 483.9	341.0 * 271.0	79.2 * 116.7	1037.3 * 671.1	1567.0 * 1040.3	1281.6 * 654.1	1476.3 ± 770.4
	3	236.2 ± 199.9	899.5 ± 700.7	492.0 ± 378.1	83.7 ± 92.6	1312.5 * 653.2	1351.2 * 620.9	1212.0 * 612.9	1237.1 ± 753.8
Bivalvia	1		535.5 * 406.8	261.4 ± 203.8	54.5 ± 88.3		2739.0 * 1125.2	1507.2 * 770.2	1463.4 ± 831.5
	2	143.2 ± 164.9	607.5 ± 469.1	299.4 ± 261.3	56.1 * 115,7	866.3 ± 689.3	1330.7 ± 833.5	1121.7 * 676.1	1358.2 * 750.4
	3	199.2 ± 195.4	824.7 ± 688.5	420.3 ± 379.0	48.8 ± 84.9	1145.5 ± 636.3	1238.5 * 585.3	1117.8 ± 595.3	1168.7 ± 743.3
Polychaeta	1		39.5 * 14.4	33.1 ± 21.4	18.5 * 14.0		54.8 ± 36.9	63.8 * 42.5	53.5 * 28.7
	2	15.3 ± 12.4	42.8 ± 21.4	24.2 ± 14.3	13.5 ± 7.4	32.8 * 27.0	109.2 * 320.4	37.1 ± 19.6	47.2 ± 29.0
	3	16.5 * 9.0	42.7 * 21.4	34.6 ± 21.4	21.6 ± 17.4	30.8 * 20.1	34.5 * 15.9	45.9 ± 29.8	33,8 ± 23.4
Mya truncata	1		245.2 ± 178.6	143.4 ± 172.8	17.6 ± 48.2		1664.2 ± 908.5	725.8 ± 616.2	780.1 ± 638.9
	2	61.0 * 99.0	248.2 * 215.8	190.0 * 177.2	21.3 ± 48.8	415.0 * 443.7	550.2 * 481.9	533.7 ± 410.7	587.0 * 552.5
	3	102.7 ± 114.3	404.5 * 318.3	165.7 * 158.8	27.4 *- 64.1	701.5 * 489.3	554.0 * 377.6	548.3 * 455.1	553.5 * 505.2
Astarte borealis	1		172.6 ± 182.5	32.9 ± 67.0	11.6 ± 27.4		319.4 * 291.4	360.4 * 314.4	3%.5 * 458.6
	2	.40.6 ± 48.8	213.2 ± 241.8	48.9 * 94.6	23.2 * 95.0	52.2 * 58.4	220.9 * 164.1	225.7 * 215.9	438.2 ± 235.8
	3	53.2 ± 88.9	230.9 ± 256.6	155.9 ± 211.0	3.9 ± 10.6	82.8 ± 77.0	191.5 ± 145.1	290.1 ± 244.2	288.0 ± 231.9
Astarte montagui	1		49.9 ± 65.7	3.1 * 11.5	0.1 ± 0.4		58.2 * 59.5	51.4 ± 43.4	147.3 * 94.5
	2	3.1 ± 8.2	74.7 ± 76.1	2.7 ± 5.9	3.2 ± 12.4	9.6 ± 10.9	37.2 ± 22.9	59.8 ± 65.4	166.7 ± 95.1
	3	1.7 * 5.1	103.1 * 93.4	8.6 ± 18.4	0	13.4 ± 14.6	46.5 ± 47.3	59.9 ± 57.5	161.7 * 94.9
Serripes groenlandicus	1		13.6 ± 26.3	1.2 ± 5.7	2.2 ± 10.8		360.5 ± 367.3	186.6 ± 206.8	28.4 ± 61.1
	2	0	26.8 ± 48.2	0	0.1 ± 0.6	128.0 ± "147.6	281.6 ± 288.6	157.5 ± 183.7	58.1 ± 113.4
	3	0	21.8 ± 57.6	0.2 ± 0.9	0	111,5 * 149.7	197.1 ± 178.4	80.5 * 118.8	52.5 ± 134.5
Hiatella arctica	1		34.0 * 51.5	23.4 ± 62.6	3.3 ± 12.3		126.7 * 1%.2	6.4 ± 16.9	7,8 ± 24.9
	2	19.4 * 40.0	17.1 * 31.2	18.4 * 47.6	0	69.1 * 324.4	20.6 * 39.6	3.4 * 9.4	16.2 * 43.1
	3	28.2 * 51.1	25.4 * 43.6	30.1 * 73.4	0.5 * 1.9	3.3 * 15.9	20.1 * 42.8	0.2 * 0.7	11.0 ± 30.6
Macoma calcarea	1		9.0 ± 16.0	4.6 * 6.9	2.4 ± 6.6		73.1 * 41.1	67.0 ± 41.4	45.4 * 37.7
	2	2.9 ± 7.4	16.6 ± 21.3	3.1 * 7.7	0	90.2 ± 63.0	67.6 * 37.8	65.7 * 65.3	36.32 40.7
	3	6.1 ± 11.2	11.7 ± 21.0	4.1 ± 8.1	2.5 ± 8.3	98.4 ± 67.4	64.9 * 38.7	55.6 ± 37.1	38.4 * 32.4

[1] Bay 7 = reference; Pay 9 = heavy dispersed oil; Pay 10 = light dispersed oil; Bay 11 = surface oil spill.
[2] Period 1 = pre-spill, September 1980; Period 2 = pre-spill, August 1981; Period 3 = peat-spill, September 1981.
[3] All taxa but ostracods, cumaceans and amphipods.

transects. Cross and Thomson (1981) reported relatively high variability on this scale for most groups and dominant species. Distributions of fauna collected in 1980 ranged from relatively even to relatively patchy, depending on species; even greater extremes of variability were observed among the large numbers of less common species in the study area.

Spatial Effects

Among-transect within-bay variability was greater at 3 m than at 7 m depth. Of the three groups of organisms whose densities and biomasses were examined by ANOVA (bivalves, polychaetes and total infauna), variation among transects within bays was significant in all cases at 3 m depth (Tables 6 and 7). At 7 m depth variation among transects was significant for bivalve density and biomass (4 bay/2 period analysis) and for polychaete density and biomass (both analyses). Results for the individual species whose densities were examined were similar. At 3 m depth, among-transect variation was significant for all but the holothurian *Myriotrochus rinkii* and *Mya truncata*. At 7 m depth, the densities of 4 of 7 species (3 bay/3 period analysis) and 5 of 7 species (4 bay/2 period) varied significantly among transects. In general, variability on this relatively small scale was highly significant at 3 m depth and only marginally significant at 7 m depth.

Among-bay variability, like among-transect variability, was greater at 3 m depth than at 7 m depth. For both types of analysis, bay effects were significant for 12 of 13 variables at 3 m depth; at 7 m depth variability among bays was significant in only 5 and 6 of 13 cases in 3 bay/3 period and 4 bay/2 period analyses, respectively. At 3 m depth, Bay 9 supported the

Table 6. Three-factor analyses of variance (ANOVA) for tha biomasses and densities of major taxa and selected species in three bays et Cape Hett. Transects are nested within bays. All three sampling periods[1] and only Bays 9, 10 and 11[2] are considered. F-values are shown with significance levels (ns = P>0.05; * P≤0.05, ** P≤0.01, *** P≤0.001).

			Source of Variation and df[3]				
			Period 2,6 or 18	Bay 2,6 or 18	Period x Bay[4] 4,6 or 18	Tr-t (Bay) 6,187	Per X Trans (Bay) 12,187
3 m	Biomass (g/m^2)	Total infauna	0.66 ns	32.90 ***	0.04 m	10.54 ***	0.67 m
		Polychaeta	0.95 ns	16.81 ***	0.26 os	6.40 ***	0.24 ns
		Bivalvia	0.38 ns	41.48 ***	0.17 ns	7.45 ***	0.92 ns
	Density ($no./m^2$)	Total infauna	1.60 ns	38.01 ***	0.22 ns	7.24 ***	0.93 ns
		Polychaeta	0.73 OS	30.03 ***	0.12 ns	4.80 ***	0.99 ns
		Bivalvia	1.64 ns	27.64 ***	0.54 ns	9.22 ***	1.17 m
		Mya truncata	6.25 **	115.55 ***	2.11 ns	1.45 ns	0.57 ns
		Astarte borealis	1.00 ns	15.45 ***	0.76 ns	9.28 ***	0.93 ns
		Astarte montagui	0.70 ns	14.68 ***	0.17 ns	28.19 ***	1.14 ns
		Thyasiridae spp.	0.30 ns	37.41 ***	0.0$ na	10.05 ***	0.90 ns
		Euchone analis	2.% ns	39.41 ***	1.58 na	5.06 ***	1.45 ns
		Myriotrochus rinkii	1.14 ns	21.27 ***	0.50 ns	1.56 ns	1.39 OS
		Capitella capitata	0.48 m	2.73 na	0.03 ns	8.00 ***	1.78 ns
7 m	Biomass (g/m^2)	Total infauna	7.97 **	4.11 *	1.55 ns	1.15 ne	1.32 ns
		Polychaeta	5.01 *	0.16 ne	1.14 ns	2.84 *	0.9U ns
		Bivalvia	6.55 **	3.41 ns	1.52 ns	1.41 ns	1.34 ns
	Density (m./m^2)	Total infauna	8.28 *	19.53 **	3.34 ns	0.55 ne	2.40 **
		Polychaeta	0.12 m	1.54 ne	3.23 *	2.84 *	1.59 ns
		Bivalvia	5.43 *	12.40 **	0.58 m	1.03 ns	2.40 **
		Mya truncata	4.63 ne	2.24 ne	0.55 ns	2.70 *	2.10 *
		Astarte borealis	0.32 ns	0.78 ns	0.26 ns	3.32 **	2.47 **
		Aatarte montagui	0.11 ns	14.63 ***	1.40 ns	1.91 ns	1.46 na
		Thyasiridae spp.	1.83 ns	169.78 ***	0.63 ns	0.77 M	0.82 ns
		Euchone anal is	2.14 ns	1.68 ns	2.67 na	1.01 ns	2.01 *
		Myriotrochus rinkii	1.03 ns	25.84 ***	0.89 ns	4.31 ***	1.07 ns
		Capitella capitata	0.30 ns	0.93 m	0.70 ns	4,87 ***	0.59 ns

1 Period 1 = pre-spill, September 1980; Period 2 = pre-spill, August 1981; Period 3 = pxt-spill, September 1981.
2 Bay 9 = heavy dispersed oil; Bay 10 = light dispersed oil; Bay 11 = surface oil spill.
3 Win-e period x transect (bay) interaction was ns, it was pooled with transect (bay) effect to test main effects; where period x transect (bay) was significant (P<0.05), transect (bay) alone was used to test main effects.
4 The Period x Bay term is the test-of oil effects.

Table 7. Three-factor analyses of variance (ANOVA) for the biomasses and densities of major taxa and selected apec iea in four bays at Cape Hatt. Transects are nested within bays. Periods 2 and 3 only[1] and all bays (7, 9, 10 and 11)[2] are considered. F-values are shown with significance levels (ns = P> 0.05; * P≤0.05, ** P≤0. 01, *** P≤0.001).

			Source of Variat ion and df[3]				
			Per iod 1,8 or 15	Bay 3,8 or 15	Per iod x Bay4 3,8 or 15	Trans (Bay) 8,167	Per x Trans (Bay) 7,167
3 m	Biomass (g/m^2)	Total in fauna	1.20 ns	13.21 ***	0.02 ns	7.79 ***	0.37 ns
		Polychaeta	2.48 ns	9.33 ***	0.27 ns	4.69 ***	1.08 ns
		Bivalvia	0.68 ns	17.72 ***	0.01 ns	5.05 ***	0.58 ns
	Density ($no./m^2$)	Total infauna	1.44 ns	15.36 ***	0.05 ns	6.03 ***	0.36 ns
		Polychaeta	0.77 ns	13.16 ***	0.23 ns	4.30 ***	0.39 ns
		Bivalvia	0.71 na	14.75 ***	0.37 ns	5.54 ***	0.77 ns
		Mya truncata	0.39 ns	53.25 ***	0.34 ne	1.87 ns	0.24 ns
		Astarte borealis	0.23 ns	8.45 **	0.65 ns	5.36 ***	1.50 ns
		- -	0.00 ns	8.65 **	0.01 ns	13.07 ***	1.36 ns
		Thyasiridae spp.	1.26 ns	23.19 ***	0.05 ns	4.51 ***	1.02 ns
		Euchone analis	1.44 ns	30.24 ***	0.39 ns	2.66 **	1.30 ns
		Myriotrochus rinkii	3.84 ns	13,83 ***	0.69 ns	1.01 ns	0.99 ns
		Capitella capitata	1.33 ns	0,97 ns	0.07 ns	6.98 ***	1.95 ns
7 m	Biomass (g/m^2)	Total in fauna	0.17 ns	0.73 ns	1.06 ns	1.48 na	1.12 ns
		Polychaeta	1.23 ns	1.81 ns	1.28 ns	2,23 *	0.58 ns
		Bivalvia	0.02 ns	1.15 ns	1,11 ns	2.19 *	1.25 ns
	Density ($no./m^2$)	Total in fauna	0.16 ns	11.46 **	5.30 *	0.52 ns	3.10 **
		Polychaeta	0.16 ns	1.76 ns	3.14 ns	3.44 **	1.77 ns
		Bivalvia	0.02 ns	2.70 ns	0.58 ns	'2.40 *	2.12 *
		Mya truncata	0.40 ns	3.15 ns	0.90 ns	1.20 ns	2.01 *
		Astarte borealis	0.06 ns	6.64 **	0.98 ns	2.42 *	1.73 ns
		Astarte montagui	0.00 ns	20.98 ***	0.78 ns	2.32 *	1.20 ns
		Thyasiridae spp.	0.00 ns	21.42 ***	0.35 ns	3.40 **	0.66 ns
		Euchone analis	0.24 ns	2.21 ns	2.13 ns	1.07 ns	2,15 *
		Myriotrochus rinkii	0.15 ns	12.44 ***	2.04 ns	2.11 *	1,22 ns
		Cap itella capitata	0.32 ns	0.24 ns	0.92 ns	2.44 *	0.75 ns

1 period 2 = pre-spill, August 1981; Period 3 = peat-spill, September 1981.
2 Bay 7 = reference; Bay 9 = heavy dispersed oil; Bay 10 = light dispersed oil; Bay 11 = surface oil spill.
3 Where period xtransect(bay)interaction was na, it was pooled with transect (bay) effect to teat main effects; where period x transect (bay) was significant (P< 0.05), transect (bay) alone was used to test main effects.
4 The Period x Bay term" is the teet of oil effects.

highest abundances and biomasses of in fauna. For 33 of 38 period/variable combinations at 3 m depth, the ranking of bays was Bay 9 > 10 > 7 > 11 (Tables 4 and 5). At 7 m depth, 4 of 13 variables differed significantly among bays in both types of analysis, viz. densities of Astarte montagui, Thyasiridae, M. rinkii and total in fauna (Tables 6 and 7). Densities of bivalves and of Astarte borealis and biomass of total in fauna each differed among bays in only one of two analyses. At this depth, patterns of among-bay variability were less consistent for variables and periods; in general, Bay 9 still ranked first and Bay 11 last, with the notable exception of Astarte montagui, whose densities were considerably higher in Bay 11 during all 3 periods (Table 4).

Temporal Effects

Temporal effects, based on the 4 bay/2 period analysis, were not significant for any variable at either depth. In the 3 bay/3 period analysis, temporal variation was significant only for the density of Mya truncata at 3 m depth, and for the densities and biomasses of bivalves and total infauna and the biomass of polychaetes at 7 m depth. The difference in results between the two types of analysis suggests that annual, rather than seasonal, variation is responsible for the observed temporal (period) effects; the 3 bay/3 period analysis includes both annual (1980/1981) and seasonal (August/September) components, whereas the 4 bay/2 period analysis includes 1981 seasonal effects alone. In most cases where period effects were significant, values were higher during 1980 than during 1981, and values for August and September 1981 were similar. Furthermore, tests for seasonal variation in the reference bay (August vs. September 1981 in Bay 7) showed no significant variability for any of the 13 variables tested. Hence the observed significant period effects in our main tests are attributable to year-to-year variability in Bays 9, 10 and 11.

Oil Effects

A temporal change (pre-spill to post-spill) that occurred in one or more of the treatment bays but not in the reference bay would constitute evidence for an oil effect. A temporal change that is not consistent among bays, either in direction or magnitude, would be detectable statistically as a significant interaction between period and bay effects.

The bay x period interaction (test of oil effects) was marginally significant for one of 26 variable/depth combinations in each type of analysis--polychaete density at 7 m in 3 bay/3 period analysis (P = 0.037) and density of total infauna at 7 m in 4 bay/2 period analysis (P = 0.026). These results indicate an effect of oil on infauna, but caution must be exercised in interpreting these interim results. Firstly, 1 or 2 type I errors in statistical inference (rejection of null hypothesis when it is true) are expected because of the large number of analyses carried out. Secondly, the inconsistencies between 3 bay/3 period and 4 bay/2 period analyses render the results equivocal. Thirdly, the two 'significant' effects were both rather marginal (0.05>P>0.025).

Thus, there is an indication, but no unequivocal proof, of effects of oil or dispersed oil on the densities or biomasses of certain dominant infaunal taxa, based on univariate analyses of data from 1 year pre-spill, 2-4 week pre-spill and 2-4 week post-spill sampling. Based on unequivocal evidence of immediate behavioral reactions to dispersed oil (see 'Immediate Post-Spill Oil Effects', below), there is reason to expect that more pronounced changes in bomass and density may be found after the 1982 data become available.

Capitella capitata

The polychaete worm Capitella capitata is an opportunistic species that is often used as an indicator of pollution (Grassle and Grassle 1977; Pearson and Rosenberg 1978). At Cape Hatt, the mean densities of Capitella capitata in Periods 1, 2 and 3 were 27.7 ± SD 71.5, 24.8 ± 42.0 and 16.4 ± 34.0 indiv./m^2, respectively. Mean densities for each period, bay and depth are given in Table 4.

Three-factor, nested ANOVA showed that the density of this species differed significantly among transects at 3 m depth and at 7 m depth in both types of analysis, indicating a patchy distribution. Differences among bays and periods, however, were not significant, nor were interaction effects in either type of analysis (Tables 6 and 7). Thus there was no evidence of an oil effect. After an oil spill in Buzzards Bay, Massachusetts, C. capitata 'monopolized the biologically denuded substrata at the heavily oiled stations for the first eleven months after the spill' (Sanders et al. 1980). The lack of an oil effect in the present study may be attributable to the relatively short interval between the spill and our last sampling period (2-4 weeks). Changes in the density of this species in 1982, approximately one year after the spill, will be monitored closely.

Size-Frequency Distribution

Exposure to oil may cause size-selective mortality of benthic animals in a variety of ways. Not all life stages of marine animals are equally susceptible to the effects of oil (Rice et al. 1975; Linden 1978). Larval stages are generally more susceptible than are adults (Wells and Sprague 1976). Dow (1978) has demonstrated, on the other hand, an instance of selective mortality of large individuals of a bivalve species. The juveniles inhabited clean surface sediments, but as they grew they tended to burrow deeper into the substrate and died when they reached an oil-contaminated layer.

Mean lengths of five bivalve species and oral ring diameters of a holothurian are shown in Table 8. Mean lengths (log transformed) of individuals in each sample were compared among bays, periods and transects, using three-factor nested ANOVAs (Table 9). The test of significance of the period x bay interaction term is the test for any oil or oil plus dispersant effect. For one of these species, the bivalve *Serripes groenlandicus*, mean sizes of the populations are underestimated because damaged individuals were not measured, and broken shells were more common among the larger individuals in our samples. There is no reason to expect any systematic differences among bays or periods in the sizes of damaged animals, however, so the analyses presented below are still valid.

Transect effects were significant for *Astarte borealis*, both at 3 m depth and at 7 m depth in both types of analysis. Mean lengths of *Mya truncata* and *Astarte montagui* also differed significantly among transects at

Table 8. Mean lengths (mm) of six species of infaunal benthic animals from four bays[1] at Cape Hatt, northern Baffin Island, during September 1980 and August and September 1981[2]. Data are expressed as mean ± standard deviation; numbers in parentheses are number of individuals collected and measured.

Spec iee	Depth	Per ird	Bay 7	Bay 9	Bay 10	Bay 11
Mya tmata	3 m	1		12.6 * 7.5 (369)	9.9 ± 7.8 (2%)	8.9 * 5.4 (79)
		2	14.1 * 7.9 (51)	15.0 * 7.1 (277)	15.8 * 8.9 (132)	10.8 * 6.2 (28)
		3	18.4 ± 7.4 (66)	16.5 ± 7.8 (338)	14.1 ± 9.2 (124)	10.4 ± 7.3 (36)
	7 m	1		28.0 * 13.9 (222)	19.3 * 13.6 (178)	17.6 * 13.0 (224)
		2	19.5 * 12.2 (101)	20.0 * 12,4 (126)	17.9 ± 14.4 (112)	17.0 ± 12.0 (213)
		3	22.2 * 13.4 (110)	22.5 * 12.9 (94)	23.0 * 12.2 (103)	19.2 * 10.9 (170)
Macoma calcarea	31a	1		11.9 * 5.1" (42)	10.7 * 4.7 (29)	19.4 * 3.8 (5)
		2	13.9 * 5.7 (lo)	11.9 ± 5.6 (72)	6,0 * 7.2 (31)	0
		3	15.0 ± 6.4 (18)	11.0 ± 5.6 (60)	11.9 ± 5.1 (21)	23 (1)
	7 m	1		13.0 ± 5.5 (253)	15.2 * 6.8 (146)	15.2 * 6.9 (88)
		2	12.5 ± 5.5 (317)	12.7 ± 5.4 (247)	14.9 ± 7.1 (120)	13.0 ± 7.2 (93)
		3	13.0 ± 5.6 (320)	12.8 ± 5.2 (237)	13.4 ± 7.0 (149)	14.9 ± 7.6 (81)
Astarte borealis	3m	1		12.8 ± 7.5 (290)	8.1 ± 8.7 (86)	10.9 ± 7.1 (29)
		2	10.6 * 7.5 (99)	11.0 * 7.8 (454)	8.9 ± 8.6 (106)	9.7 * 7.3 (27)
		3	9.4 ± 12.8 (96)	11.5 ± 8.3 (445)	10.9 ± 10.5 (209)	10.4 ± 6.9 (14)
	7 m	1		12.7 ± 7.0 (633)	13.2 * 8.5 (527)	13.6 ± 8.6 (551)
		2	9.8 ± 6.0 (238)	11.3 ± 7.8 (475)	11.4 ± 8.2 (460)	12.8 ± 8.9 (611)
		3	9.8 * 6.2 (301)	11.0 ± 7.2 (497)	12.5 * 9.0 (434)	10.8 * 8.3 (591)
Astarte montagui	3m	1		11.1 ± 2.7 (205)	12.6 * 2.7 (8)	5.7 * 3.1 (3)
		2	9.0 * 4.3 (23)	10.1 ± 3.6 (333)	5.1 * 4.5 (34)	13.0 * 4.6 (3)
		3	5.9 * 4.0 (19)	10.0 * 4.1 (462)	9.3 * 4.5 (41)	3.3 * 0.6 (3)
	7m	1	-	9.8 * 3.5 (268)	10.0 ± 4.1 (209)	10.0 ± 3.8 (638)
		2	8.5 ± 4.0 (63)	8.5 ± 4.5 (212)	10.6 ± 4.8 (242)	9.8 ± 4.2 (673)
		3	9.8 ± 3.9 (68)	8.9 ± 4.3 (218)	9.0 ± 4,3 (326)	9.6 * 4.2 (724)
Serripes groenlandicus	3m	1		13.5 ± 5.6 (26)	22 (1)	26 (1)
		2	0	16.2 ± 4.7 (29)	0	6.3 ± 3.9 (4)
		3	0	14.9 ± 11.4 (17)	10 (1)	0
	7m	1		26.0 ± 12.6 (74)	29.0 * 12.2 (34)	21.4 * 8.4 (15)
		2	17.8 * 11.4 (29)	24.9 ± 13.6 (35)	29.0 ± 14.5 (21)	20.6 * 10.4 (18)
		3	20.3 * 12.5 (31)	24.4 ± 12.3 (39)	20.0 ± 10.7 (16)	26.4 ± 12.4 (9)
Myriotrochus rinkii[3]	3 m	1		2.3 * 1.1 (517)	2.7 * 1.1 (210)	2.7 * 1.0 (137)
		2	2.6 ± 0.9 (153)	2,3 ● 0.13 (410)	3.0 * 13.9 (104)	2.8 ± 1.1 (136)
		3	2.4 * 0.8 (166)	2.3 ± 0.8 (400)	2.8 * 1.0 (l%)	2.6 ± 1.0 (134)
	7 m	1		3.2 ± 1.0 (136)	4 (1)	3.6 ± 0.8 (39)
		2	3.1 ± 0.9 (29)	3.2 ± 0.9 (46)	3.5 ± 0.7 (11)	3.7 * 0.5 (6)
		3	3.1 * 0.9 (7)	2.9 * 0.8 (91)	3.5 (2)	2.8 ± 0.9 (16)

1 Bay 7 = reference; Bay 9. heavy dispersed oil; Bay 10 = light dispersed oil; Bsy 11 = surface oil spill.
2 Period 1 = pre-spill, September 1980; Period 2 = pre-spill, August 1981; Period 3 = pxt-spill, September 1981.
3 Diameter Of calcareous Oral ring.

Table 9. Results of analyses of variance on mean lengths (in each sample) of four bivalve species. and the mean oral ring diameter of the holothurian Myriotrochus rinkii. F-values are shown with significance levels (ns = P>0.05; * P<0.05; ** P<0.01, P<0.001).

			Source of Variation and df[1]						
Analysis	Depth	Species	Period 2 (1)[1]	Bay 2 (3)	Period x Bay[2] 4 (3)	Transect (Bay) 6 (8)	Per X Tran (Bay) 12 (8)	Residual df	No. of samples
3 bay/3 period[3]	3 m	Myriotrochus rinkii	1.16 ns	10.00 **	0.20 ns	1.59 l-la	1.56 Us	170	197
		Astarte borealis	0.84 ns	2.40 ns	0.02 ns	4.81 ***	0.66 Us	125	152
		Mya truncata	1.30 Us	13.23 ***	0.79 ns	4.43 ***	0.56 ns	153	1s0
	7 m	Astarte montagui	1.50 Us	1.16 ns	0.93 ns	3.09 **	1.01 us	179	206
		Astarte borealis	4.20 *	0.60 ns	1.26 ns	3.73 **	0.76 ns	186	213
		Mya truncata	0.32 us	6.78 **	2.72 ns	2.38 *	1.02 I-IS	181	208
		Macoma calcarea	3.53 ns	2.08 ns	1.62 us	0.81 us	0.58 ns	1s2	209
4 bay/2 period[4]	3 m	Myriotrochus rinkii	3.59 ns	5.76 *	0.06 US	1.50 ns	2.05 *	152	176
		Astarte borealis	0.08 Us	1.39 Us	0.27 ns	3.91-	0.59 ns	117	141
		Mya truncata	0.10 ns	6.75 **	0.s3 US	2.37 *	0.51 m"	129	153
	7m	Astarte montagui	0.09 ns	0.82 ns	1.60 ns	2.58 *	1.05 Us	14s	172
		Astarte borealis	0.45 ns	1.79 Us	1.46 ns	2.79 **	0.91 ns	161	185
		Mya truncata	1.76 I-IS	2.09 US	1.22 ns	1.45 ns	1.33 ns	159	183
		Macoma calcarea	2.89 ns	0.89 ns	3.13 ns	0.55 0s	0.33 Us	161	185

[1] Numerator df are shown for 3 bay/3 period analysis, followed by 4 bay/2 period analysis (in parentheses). Den[redacted] df are residual df for transect effects. Were period x transect (bay) interaction was US, it was pooled with transect (bay) effect to test main eff.sets and the period x bay interaction; denominator df are 18 (3/3 analysis) or 16 (4/2 analysis). Were pried x transect (bay) was significant (@.05), transect (bay) alone was used to test main effects and the period x bay interaction; denominator df ace 8 (4/2 analysis).

[2] The Period x Bay term is the test of oil effects.

[3] Bays 9 (heavy dispersed oil), 10 (light dispersed oil) and 11 (surfs% oil spill); Periods 1 (pre-spill, September 1983); 2 (pre-spill, August 1981), and 3 (post-spill, September 19$1).

[4] Bays 7 (reference), 9, 10 and 11; Periods 2 and 3.

3 and 7 m depths, respectively, again according to both types of analysis. Bay effects, i.e. differences among bays after accounting for differences among transects within bays, were significant only for Mya truncata and Myriotrochus rinkii at 3 m depth (both types of analysis) and for M. truncata at 7 m depth (3 bay/3 period only). Mya truncata were smaller in Bay 11 than in any other bay at both depths, and the mean oral ring diameter of M. rinkii was smaller at 3 m depth in Bay 9 than in Bays 10 or 11 (Table 8). Period effects were marginally significant for A. borealis at 7 m depth (only in 3 bay/3 period analysis; $P = 0.032$). Interaction effects were not significant at either depth for any of the species. The absence of any period x bay interaction indicates that no effects of oil on mean size were detectable.

Thus, most of the systematic variation in mean sizes of the infaunal species examined was attributable to spatial effects. This spatial variability was evident on both small (transect) and relatively large (bay) scales, and occurred in all but one of the species tested (Macoma calcarea). There was no evidence of any oil-related change in size structure of the populations.

Weight-Length Relationships of Bivalves

Exposure to crude oil may cause physiological changes in marine invertebrates. In bivalves these changes may be reflected in the dry weight-length relationship (Stekoll et al, 1980). The dry weight-length relationship of four bivalve species is being used as an indicator of sublethal effects of oil in the experimental bays at Cape Hatt.

For three species of bivalves (*Mya truncata, Macoma calcarea* and *Astarte borealis*), approximately 50 individuals from the middle 7 m transect in each of the three bays sampled in September 1980 were measured and weighed. Analysis of scatter plots of the original data and of residuals produced by regression analyses indicated that the weight-length relationship of these animals was best expressed by a power curve ($y = ax^b$) rather than by exponential (y = sex), linear (y = a + bx) or logarithmic (y = a log x) functions (Cross and Thomson 1981). This type of weight-length relationship was expected *a priori* and is typical of most animals.

Weight-1ength analyses in the present report include a fourth species, *Serripes groenlandicus,* a fourth bay (Bay 7), and all three periods. Regression equations were calculated as above for each species, period and bay, Analyses of covariance were used to assess among-bay and among-period variations in the slopes of the regression lines and in dry weights adjusted for length (Table 10). The slope of the regression line is the power to which length must be raised in order to estimate weight (b in the expression y = ax b). The first part of the analysis of covariance is a test of equality of slopes. If the slopes for different bays and periods are similar, then the rate of gain in weight with increasing length is consistent, If slopes are significantly different among bays or periods, interpretation of the remainder of the analysis is ambiguous. The second part of the analysis compares weights in different bays and periods after adjustment for any differences in length. If adjusted weights (i.e. weight at a standard length) are significantly different, then at any given length animals are heavier in some bays or periods than in others.

Table 10. Analyses of covariance of difference in dry meat weight, using length as the covariate, for bivalves collected at a depth of 7 m at Cape Hatt, northern Baffin Island, during September 1980 and August and September 1981. F-values sre given with significance levels (ns = P>0.05; * P≤0.05; ** P≤0.01; *** P≤ 0.001).

Test	Species	df[1] ->	Equality of Group Means: Period 2 (1)	Equality of Group Means: Bay 2 (3)	Equality of Group Means: Period x Bay 4 (3)	Group Means Ranking[2]	Equality of Slopes: Period 2 (1)	Equality of Slopes: Bay 2 (3)	Equality of Slopes: Period x Bay 4 (3)	No. of specimens
3 bay/3 period[3]	*Astarte borealis*		16.08 ***	0.28 ns	2.11 ns	** ** 1 > 2 > 3	0.21 ns	2.07 ns	1.32 ns	434
	Macoma calcarea		4.79 **	0.05 ns	0.% ns	* 1> 2 ≃ 3	1.52 ns	0.18 ns	1.91 ns	419
	Mya truncata		8.24-	2.37 ns	1.07 ns	*** 1 > 2 ≃ 3	3.27 ns	1.87 ns	1.65 ns	429
4 bay/2 period[4]	*Astarte borealis*[5]						0.37 ns	7.28 ***	0.42 ns	390
	Macro calcarea[5]						2.43 ns	2.96 *	5.49 **	394
	Mya truncata[5]						2.19 ns	5.10 **	0.78 ns	398
	Serripes groenlandicus		2.09 ns	15.33 ***	1.45 ns	*** 7> (9 ≃ 10 ≃ 11)	2.21 ns	0.89 ns	0.91 ns	197

1 Numerator df are shown for 3 bay/3 period analysis followed by 4 bay/2 period (in parentheses).
2 Significance determined with t-tests.
3 Bays 9 (heavy dispersed oil), 10 (light dispersed oil) and 11 (surface oil spill); Periods 1 (pre-spill, September 1980), 2 (pre-spill, August 1981) and 3 (post-spill, September 1981).
4 Bays 7 (reference), 9, 10 and 11; Periods 2 and 3.
5 Results of 'Equality of Group Means' not shown because of heterogeneity of slopes of regression lines.

When 3 bays (9, 10 and 11) and all 3 periods were considered, slopes of the regression lines did not vary significantly among periods or bays for any of the three species. There was also no evidence of significant differences in weight-at-length in different bays, or of a bay x period interaction. The lack of an interaction indicates that there was no detectable oil effect. The mean weight of individuals of any particular length, however, differed significantly among periods for all three bivalve species. In each case, mean weight was significantly greater in Period 1 (September 1980) than in Periods 2 or 3 (August and September 1981); mean weights in Periods 2 and 3 were significantly different only for <u>Astarte borealis</u>, where weight was greater in Period 2 than in Period 3 (Table 10).

When all four bays and only Periods 2 and 3 were considered, significant differences in regression line slopes did occur for each species except <u>Serripes groenlandicus</u>. Adjusted weights of <u>Serripes</u> differed significantly among bays--individuals from Bay 7 were heavier than those from other bays (Table 10)--but the period and interaction terms were non significant. Regression line slopes differed significantly among bays for <u>Astarte borealis</u>, <u>Macoma calcarea</u> and <u>Mya truncata</u>. For each species, young individuals from Bay 7 (reference bay) were heavier at a given length than were those from the treatment bays. For A. <u>borealis</u> and <u>M</u>. <u>truncata</u>, actual differences in slopes were relatively small (Figs. 3 and 4), and the differences were consistent in August and September 1981 (Table 10). For <u>Macoma calcarea</u>, however, differences were not consistent between pre- and post-spill periods (i.e. the period x bay interaction was significant-- Table 10). Inspection of the regression lines for <u>Macoma calcarea</u> (Fig. 5) indicates that young individuals from Bay 7 in Period 3 (September) were

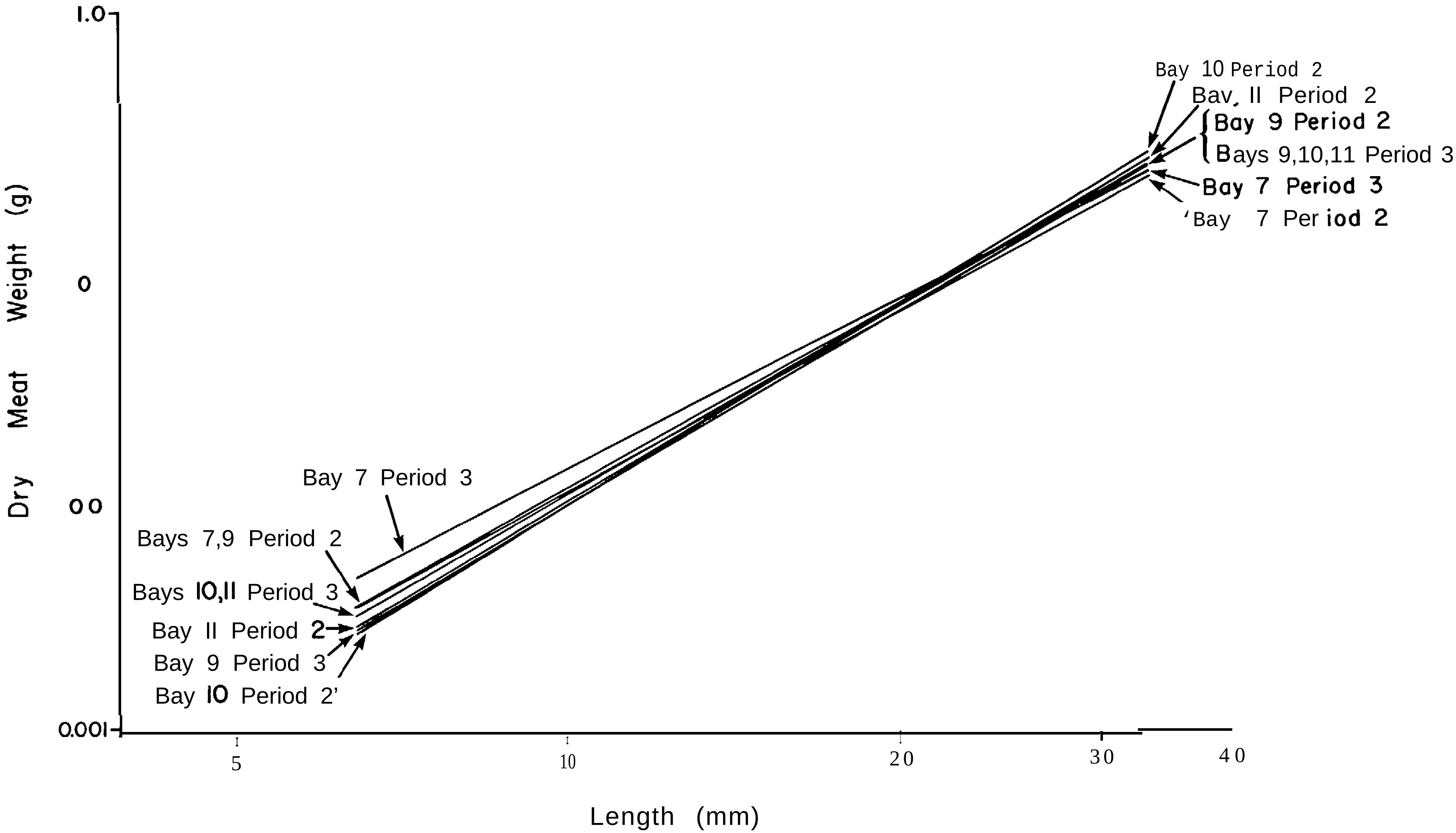

Figure 3. Least squares regression lines of dry meat weight vs. length for *Astarte borealis* in four bays at Cape Hatt, northern Baffin Island, during August and September 1981.

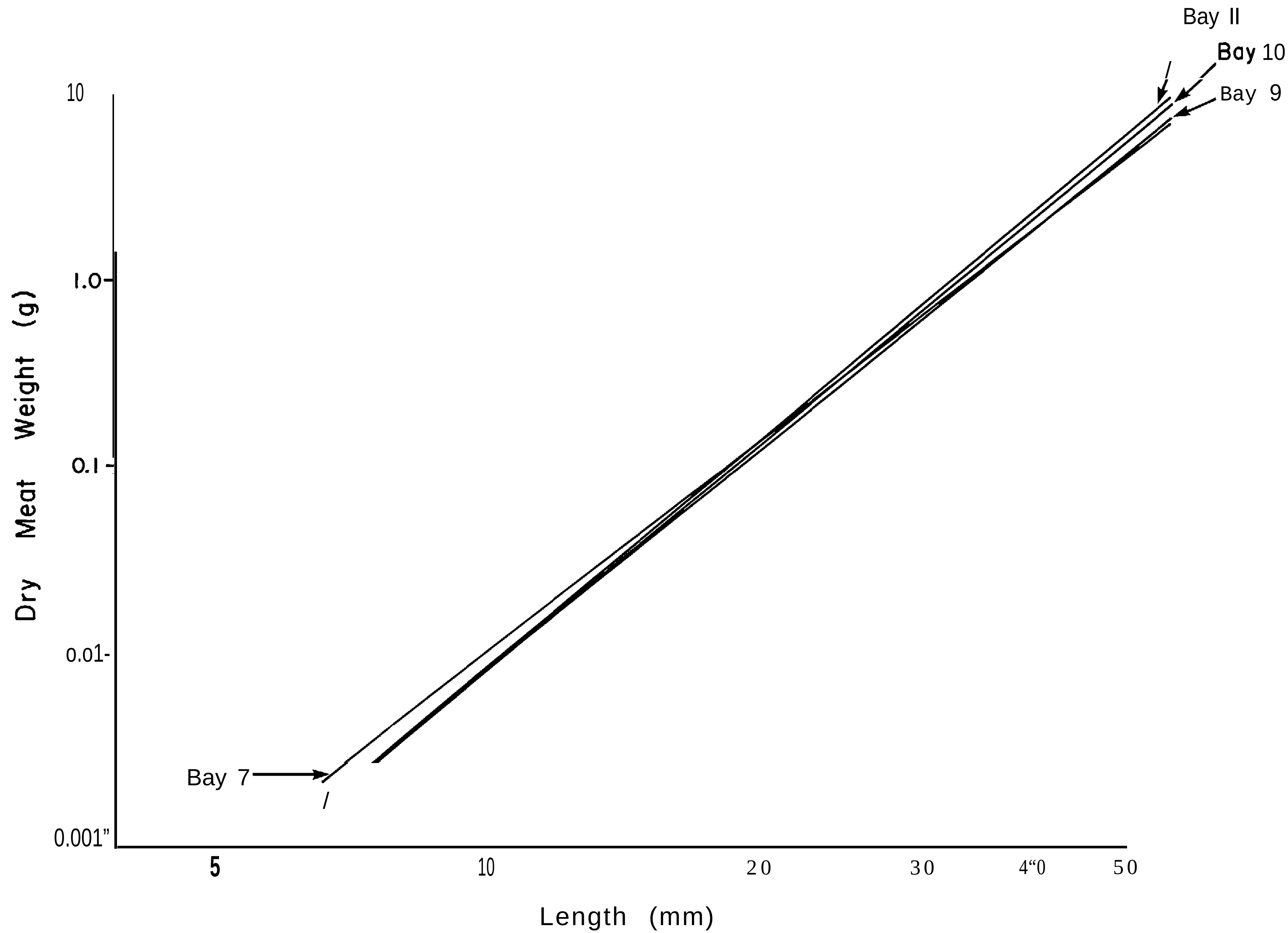

Figure 4. Least squares regression lines of dry meat weight *vs*. length for *Mya truncata* in four bays at Cape Hatt, northern Baffin Island, during August and September 1981.

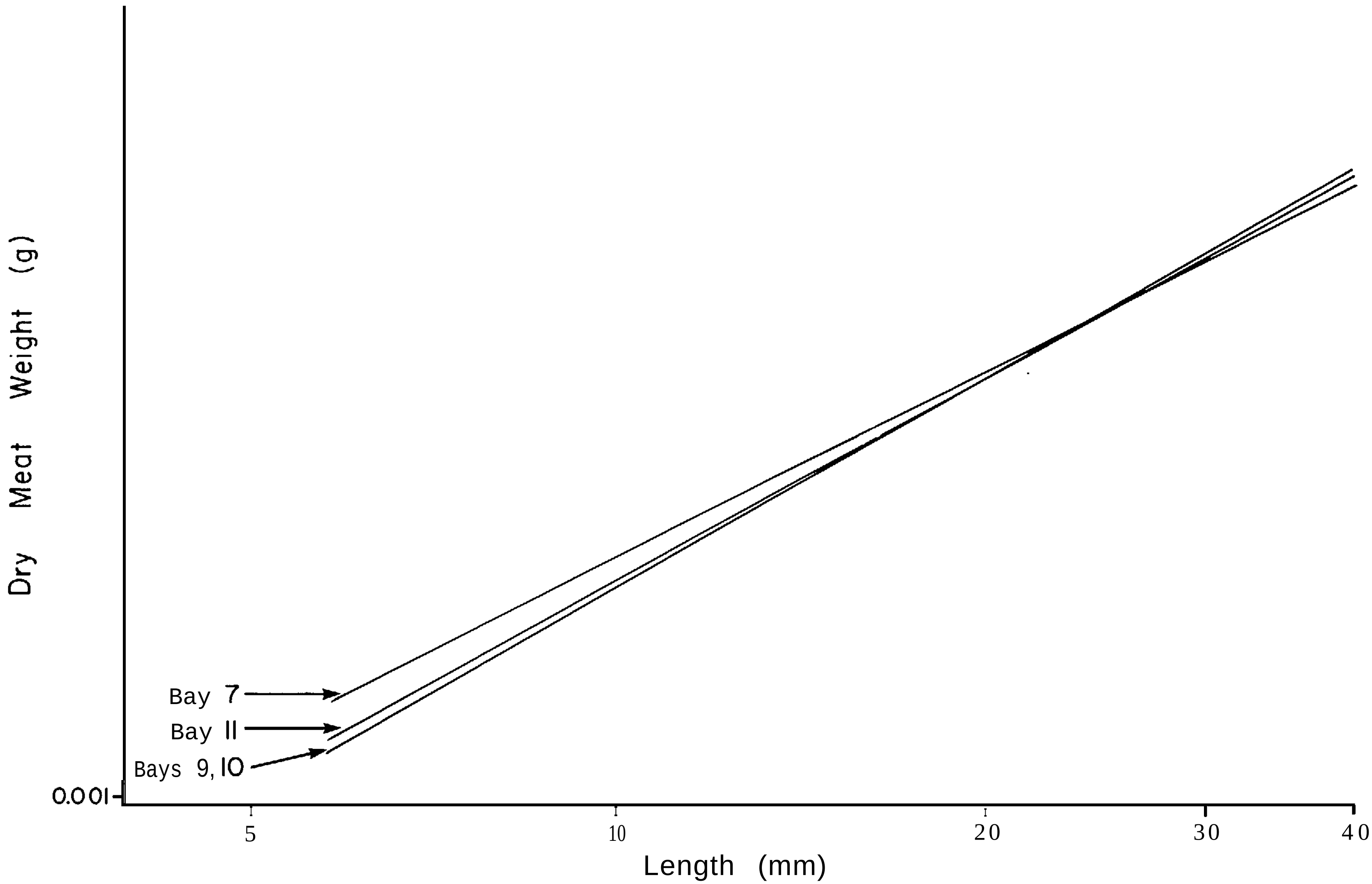

Figure 5. Least squares regression lines of dry meat weight vs. length for *Macoma calcarea* in four bays at Cape Hatt, northern Baffin Island, during August and September 1981.

heavier at a given length than were those in Bay 7 during Period 2, and heavier than were those in the other bays and other periods. For these three species, the heterogeneity of slopes precludes an unambiguous interpretation of tests for among-period and among-bay differences in mean weights after compensating for the effect of length on weight.

Based on these analyses, the only substantial evidence of an oil effect is the significant period x bay interaction effect for the slope of the weight-length curve of Macoma calcarea (above). Differences in regression line slopes (Fig. 5) were evident only in the reference bay (Bay 7), where M. calcarea increased in weight relative to length between August and September 1981. Such a disproportionate increase in body tissue likely represents a natural seasonal increase in gonadal or storage materials, which are necessary to meet metabolic requirements in the winter. Increase in length in Macoma balthica apparently ceases during winter in temperate, boreal and arctic waters (Green 1973; Buekema and de Bruin 1977; Chambers and Milne 1979; Bachelet 1980). In the Dutch Wadden Sea (Buekema and de Bruin 1977), M. balthica increased in length and tissue weight from March to June; in the subsequent 8-9 months length remained constant, whereas almost two-thirds of the summer's increase in dry tissue weight was lost. Thus the observed seasonal increase in weight relative to length for M. calcarea in the reference bay is not unexpected. In contrast, the lack of such an effect in the other (oiled) bays may be attributable to oil effects on feeding, gonadal development or metabolic processes. Oil has been reported to interfere with feeding behaviour (Atema and Stein 1974; Atema 1976; Hyland and Miller 1979; Augenfeld 1980) and to increase metabolic rate (Hargrave and Newcombe 1973; Fong 1976).

Community Structure

Approach

Perturbation of the benthic marine environment often results in large-scale changes in infaunal community structure (Pearson and Rosenberg 1978). Faunal changes resulting from the introduction of oil may be drastic and the degree of change is related to the intensity and duration of oiling (Sanders et al, 1980). One of the best approaches for detecting oil effects appears to be the community or ecosystem approach (Mann and Clark 1978; Elmgren et al. 1980).

We are using changes in benthic community structure as the overall test of oil effects in the experimental bays at Cape Hatt. The term community, in these tests, refers to an assemblage of benthic animals that occur together. Since distribution of benthic animals may be affected by currents, food availability, substrate and depth, similar assemblages of animals may be found under similar environmental conditions. Factor analysis is being used to identify the assemblages found in the experimental bays at Cape Hatt. The abundance of each group in each sample is also computed in this analysis (factor score). A high factor score indicates that the assemblage of animals associated with a factor is common in the sample in question; a low or negative factor score indicates that the animals in the assemblage are rare or absent in the sample, and that any species negatively associated with the factor are common. The factor analysis thus reduces a large number of species variables to a smaller number of assemblage variables. By testing for statistically significant among-bay and among-period differences in factor scores (representing species assemblages), we are testing for differences in overall community composition.

A multivariate analysis of variance is being used to determine the significance of differences in factor scores among bays and periods. This analysis simultaneously considers scores for all factors determined in factor analysis. The test for oil effects is a test for changes in benthic community composition in the experimental (oiled) bays that do not occur in the reference bay. This test is represented by the interaction term in the multivariate analysis of variance. The analysis also tests for differences in community composition among sampling periods and among bays. Graphical representations of the results of the MANOVA's were also produced.

Cross and Thomson (1981) showed that there were significant between-depth differences in the infaunal communities in the bays at Cape Hatt. Furthermore, differences between depths were not consistent among bays (the bay by depth interaction term was significant). Inclusion of depth as a term in the overall analysis would have rendered interpretation difficult if not impossible. Depths were, therefore, treated separately; factor analyses and multivariate analyses of variance were performed on each depth separately.

The species considered for analysis were those that accounted for 1% or more of total infaunal numbers or were found in more than 100 samples at each depth (Appendices 3 and 4). In this way 21 taxa representing 85% of total numbers at the 3 m depth and 27 taxa representing 84% of total numbers at the 7 m depth were selected for factor analyses. Either density or biomass data would be adequate for the detection of large-scale change, but subtle faunal changes would be more readily detected in density data. The biomass data are dominated by the presence and abundance of older individuals and are relatively insensitive to numerical changes in younger individuals. Hence analyses were performed on density data.

The results of the factor analyses applied to the most common species collected at the 3 m and 7 m depths during all time periods and from all bays are summarized in Tables 11 and 12, respectively (see Appendices 3 and 4 for complete results). At the 3 m depth, 6 factors with eigenvalues >1 were extracted. These accounted for 62.4% of the variance represented by the 21 species variables. At the 7 m depth, 9 factors with eigenvalues >1 were extracted; they accounted for 59.7% of the variance represented by the 27 species variables. Each of these factors can be considered as representing a group of species that tend to occur together and whose densities vary more or less proportionately. Tables 11 and 12 list the species whose densities were strongly correlated with each of the factors. Some factors also represent certain species (those with negative signs) that tend to be absent or rare at locations where the the other species are common.

Factor scores were calculated for each sample and are summarized for each bay and time period at the 3 m depth in Fig. 6 and at the 7 m depth in Fig. 7.

Differences in community composition among bays and periods were assessed with multivariate analyses of variance using, as dependent variables, the factor scores for each of the factors derived in the previous analyses. These analyses test for differences in community composition among

Table 11. Results of factor analysis of the 21 most abundant benthic animals collected at 3m depth at Cape Hatt, northern 13af fin Island, during September 1980 and August and September 1981. The values shown are the correlations between the log transformed densities of various species (the original variables) and each of the 6 factors determined in the analysis. Species whose densities were weakly correlated with a factor (-0.4 < r < 0.4) are not shown. Also shown is the variance explained by each factor.

1. Variance explained	18.2%
Astarte borealis	0.803
Astarte montagui	0.750
Thyasiridae spp.	0.673
Trichotropis borealis	0.672
Cingula castanea	0.658
Cistenides granulata	0.511
Mya truncata	0.487
Scoloplos armiger	0.480
Pholoe minuta	0.468

2. Variance explained	12.2%
Musculus discors	0.782
Nereimyra punctata	0.716
Musculus sp. juveniles	0.699
Harmothoe imbricata	0.627

3. Variance explained	10.0%
Astarte sp. juveniles	0.767
Cirratulidae spp.	0.552
Mya truncata	0.551
Euchone anal is	0.522
Thyasiridae spp.	0.474

4. Variance explained	9.3%
Myriotrochus rinkii	0.671
Retusa obtusa	0.668
Pholoe minuta	0.574

5. Variance explained	6.7%
Capitella capitata	0.770
Eteone longs	0.570

6. Variance explained	5.9%
Nemertean sp. A.	0.842
Cirratulidae spp.	0.456
Scoloplos armiger	0.429

Table 12. Results of factor analysis of the 27 most abundant benthic animals collected at 7m depth at Cape Hatt, northern Baff in Island, during September 1980 and August and September 1981. The values shows are the correlations between the log transformed densities of various species (the original variables) and each of the 9 factors determined in the analysis. Species whose densit iea were weakly correlated with a factor (-0.4 < r < 0.4) are not shown. Also shown is the variance explained by each factor.

1. Variance explained	9.8%
Thyasiridae Spp.	0.831
Macoma calcarea	0.661
Macoma sp. juveniles	0.529
Nuculana minuta	0.443
Macoma moesta	0.433
Pholoe minuta	0.414

2. Variance explained	9.1%
Astarte montagui	0.757
Astarte borealis	0.757
Praxillella praetermissa	0.628
Mya truncata	0.495
Maldane sarsi	0.448

3. Variance explained	8.1%
Myriotrochus rinkii	0.617
Cingula castanea	0.587
Retusa obtusa	0.586
Musculus niger	0.577
Serripes groenlandicus	0.526

4. Variance explained	6.0%
Moelleria costulata	0.614
Maldane sarsi	0.555
Scoloplos armiger	-0.616

5. Variance explained	5.5%
Diplocirrus sp.	0.721
Trichotropis borealis	0.556
Harmothoe imbricata	-0.423

6. Variance explained	5.5%
Cistenides granulata	0.823

7. Variance explained	5.5%
Astarte sp. juveniles	0.772
Mya truncata	0.436
Nereimyra punctata	-0.409

8. Variance explained	5.2%
Aricidea sp.	0.789
Harmothoe imbricata	0.471
Pholoe minuta	0.452

9. Variance explained	5.0%
Capitella capitata	0.762
Eteone longa	0.624

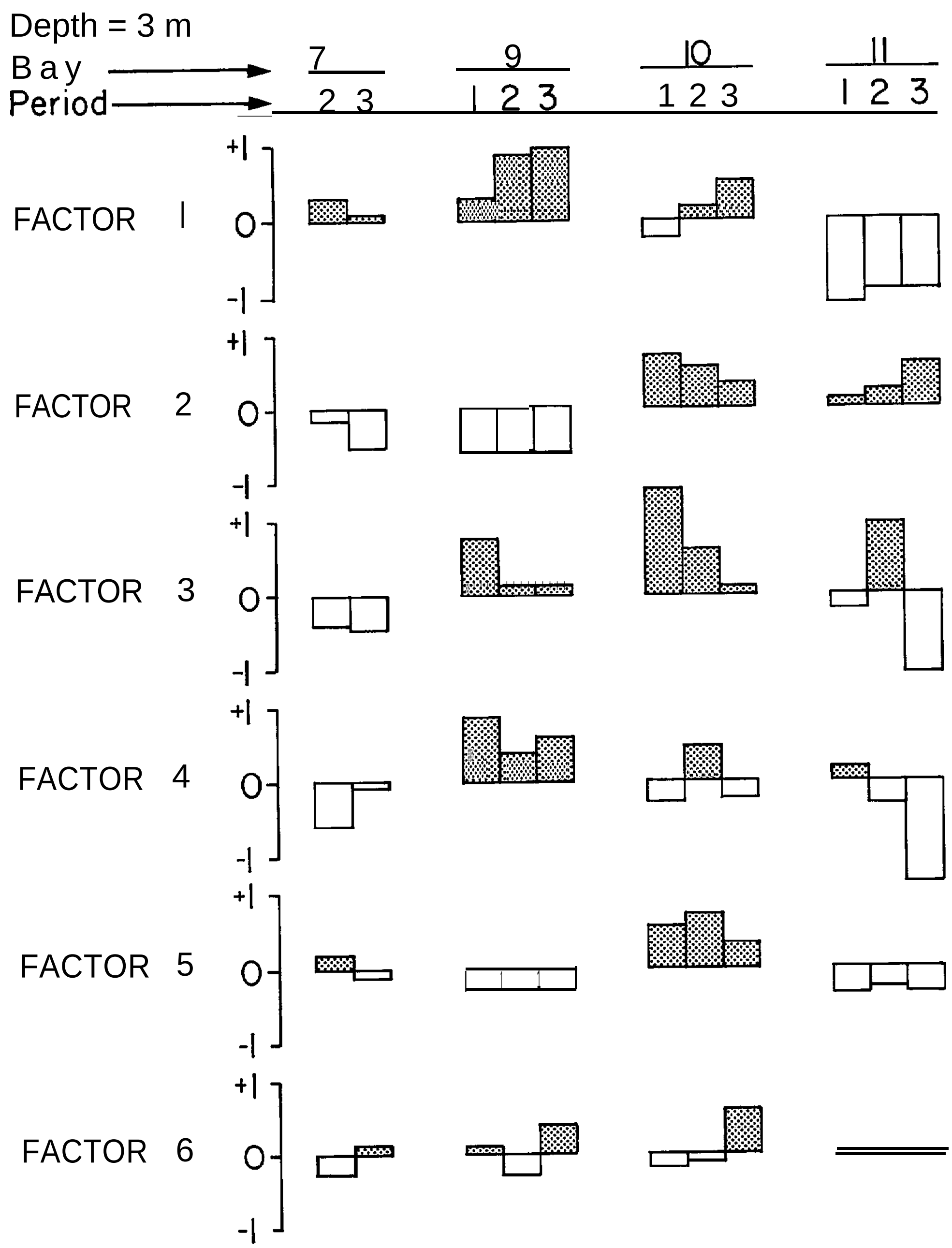

Figure 6. Mean factor scores for each period and bay at 3 m depth in four bays at Cape Hatt, northern Baffin Island, during September 1980 and August and September 1981.

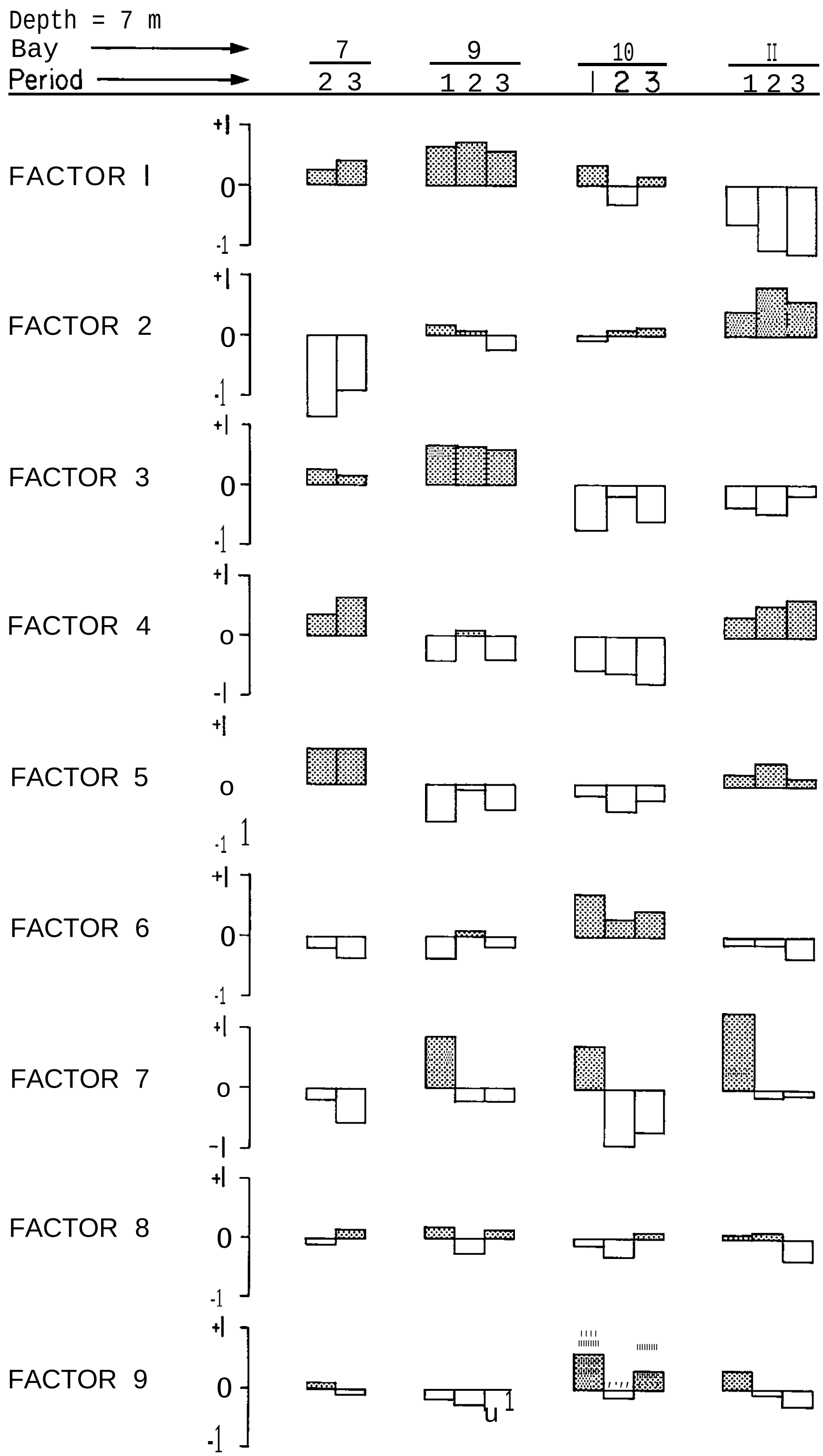

Figure 7. Mean factor scores for each period and bay at 7 m depth in four bays at Cape Hatt, northern Baffin Island, during September 1980 and August and September 1981.

bays and periods by simultaneously considering the scores for all factors. Since these factors, in turn, represent assemblages of the most common species, the analyses test for departures from the 'natural' community composition. Four separate analyses were done: for both 3 and 7 m depths using both the 3 bay/3 period and 4 bay/2 period approaches. The results of these analyses, together with (univariate) analyses of variance for each factor, are shown in Tables 13 and 14.

Spatial Effects

Most of the significant ($P<0.05$) variation in all four analyses was spatial, including both variation among transects within bays, and variation among bays. Variation among transects was significant in all four MANOVAS, in 7 of 12 univariate ANOVAs for 3 m depth, and in 11 of 18 ANOVAs at 7 m depth. This indicates a patchy distribution of infaunal assemblages on the 50 m scale at both depths. Significant variation among bays occurred with a similar frequency as that among transects: in all four MANOVAs, in 10 of 12 ANOVAs at 3 m depth, and in 14 of 18 ANOVAs at 7 m depth (Tables 13 and 14). Results of the two types of analyses (3 bay/3 period; 4 bay/2 period) were similar with respect to the frequency of significant spatial effects: variation among transects and variation among bays were significant for only a few more factors in the 3 bay/3 period analysis than in the 4 bay/2 period analysis (13 vs. 11, and 10 vs. 8 factor/ depth combinations for transect and bay effects, respectively).

The significant bay effects appear in the well-ordinated plots of group centroids, especially at the 7 m depth (Figs. 8A and 9A). In most cases,

Table 13. Multivariate and univariate analyses of variance for factor scores determined in factor analyses of in faunal density in three bays at Cape Hatt. Transects are nested within bays[1]. All three sampling periods[2] and only Bays 9, 10 and 11[3] are considered in the analyses. F-values are shown with significance levels (ns = P> 0.05; * P< 0.05; ** P< 0.01, *** P<0 .001) for univar iate ANOVAS , and with actual probabilit ies for mul tivariate ANOVAS .

Depth	Variable	df[1] =	Per iod 2,6 or 18	Bay 2,6 or 18	Period x Bay 4,6 or 18	Transect (Bay) 6,187	Per x Trans (Bay) 12,187
			F-values for each Component of Variance				
3 m	f4ANOVA						
	Pillai's trace	F ->	5.84	19.38	0.16	6.28	1.09
		P ->	0.000	0.000	0.914	0.000	0.28
		df ->	12,28	12,28	12,64	36,1122	72,1122
	ANOVAS						
	Factor 1		1.76 ns	20.52 ***	0.32 ns	16.96 ***	0.92 ns
	Factor 2		0.00 ns	8.64 **	0.39 ns	13.06 ***	1.10 ns
	Factor 3		38.67 ***	85.75 ***	1.25 ns	0.78 ns	0.84 ns
	Factor 4		1.51 ns	13.09 ***	0.13 ns	3.11 **	0.98 ns
	Factor 5		0.13 ns	6.91 **	0.09 ns	7.05 ***	1.03 ns
	Factor 6		5.57 *	0.66 ns	1.56 ns	0.93 ns	0.81 ns
7 m	MANOVA						
	Pillai's trace	F ->	0.434	31.874	0.80[4]	2.54	1.41
		P ->	0.884	0.002	0.701	0.000	0.004
		df ->	12,4	12,4	24,16	54,1104	108,1683
	ANOVAS						
	Factor 1		3.11 ns	57.01 ***	1.49 ns	2.28 *	1.79 ns
	Factor 2		0.23 ns	8.51 *	0.96 ns	1.74 ns	2.19 *
	Factor 3		0.17 ns	11.44 **	0.48 ns	3.55 **	2.84 **
	Factor 4		1.05 ns	24.78 ***	0.99 ns	1.85 ns	1.10 ns
	Factor 5		0.42 ns	7.39 **	0.96 ns	1.97 ns	1.27 ns
	Factor 6		0.08 ns	6.86 **	0,83 ns	2.40 *	1.18 ns
	Factor 7		46.06 ***	8.67 **	0.45 ns	3.19 **	0.96 ns
	Factor 8		0.34 ns	0.17 ns	0.73 ns	3.55 **	1.52 ns
	Factor 9		2.55 ns	5.52 *	0.82 ns	3.26 **	0.53 na

1 Where period x transect (bay) interaction was ns, it was pooled with transect (bay) effect to test main effects; where period x transect (bay) was significant (P<0. 05) , transect (bay) alone was used to test main effects.

2 Period 1 = pre-spill, September 1980; Period 2 = pre-spill, August 1981; Period 3 = post-spill, Se ptember 1981.

3 Bay 9 . heavy dispersed oil; Bay 10 = light dispersed oil; Bay 11 = surface oil spill.

4 Only factors 1-6 were considered in the MANOVA because numerator df " 6.

Table 14. Multivariate and univariate analyses of variance for factor scores determined in factor analyses of in faunal density in four bays at Cape Hatt. Transects are nested within bays[1]. Sampling periods 2 and 3[2] and all four bays[3] are considered in the analyses. F-values are shown with significance levels (ns = P> 0.05; * P<0. 05; ** P<0.01, *** P< 0.001) for univariate ANOVAS, and with actual probability ies for mult ivariate ANOVAS.

			F-values for each Component of Variance				
Depth	Variable	df[1] =	Per iod 1,8 or 16	Bay 3,8 or 16	Period x Bay 3,8 or 16	Transect (Bay) 8,166	Per x Trans (Bay) 8,166
3 m	MANOVA						
	Pillai's trace	F ->	3.11	5.31	1.08	3.76	0.83
		P ->	0.049	0.000	0.408	0.000	0.792
		df ->	6,11	18,39	18,39	48,996	48,996
	ANOVAS						
	Factor 1		0.07 ns	16.65 ***	0.30 ns	6.56 ***	0.89 ne
	Factor 2		0.09 ns	5.47 **	0.45 ns	8.59 ***	0.70 ns
	Factor 3		2.60 ns	41.72 ***	1.10 ns	0.87 ns	0,51 ns
	Factor 4		3.42 ns	9.05 ***	0.70 ns	1.64 ns	0.38 ns
	Factor 5		0.73 ns	3.54 *	0.18 ns	4.58 ***	0.98 ns
	Factor 6		10.21 **	1.25 ns	1.64 ns	1,13 ns	0.63 ns
7 m	MANOVA						
	Pillai's trace	F ->	0.0s	16.34	1.34	2.29	0.95
		P ->	1.000	0.000	0.218	0.000	0.589
		df ->	9,8	27,30	27,30	72,1250	72,1320
	ANOVAS						
	Factor 1		0.15 ns	16.76 ***	0,60 ns	3.78 ***	1.32 ns
	Factor 2		0.20 ns	22.45 ***	1.17 ns	1.78 ns	1.73 ns
	Factor 3		0.07 ns	4.27 *	0.41 ns	3,39 **	2.87 **
	Factor 4		0.01 ns	16.84 ***	1.22 ns	1.80 ns	0.62 ns
	Factor 5		0.73 ns	10.99 ***	0.79 ns	1.34 ns	0.52 ns
	Factor 6		0.27 ns	2.57 ns	0.13 ns	3.35 **	0.29 ns
	Factor 7		0.24 ns	5.94 **	1.05 ns	1.84 ns	0.63 ns
	Factor 8		0.22 ns	0.14 ns	1.01 ns	3.19 **	1,24 ns
	Factor 9		0.21 ns	1.95 ns	0.89 ns	2.35 *	0.41 ns

1 Where period x transect (bay) interaction was TM, it was pooled with transect (bay) ef feet to test main effects; where period x transect (bay) was significant (P<0.05) , transect (bay) alone was used to teat main effects.
2 period 2 = pre-spill, August 1981; Period 3 = post-spill, September 1981.
3 Bay 7 = reference; Bay 9 = heavy dispersed oil; Bay 10 = light dispersed oil; Bay 11 = surface oil spill.

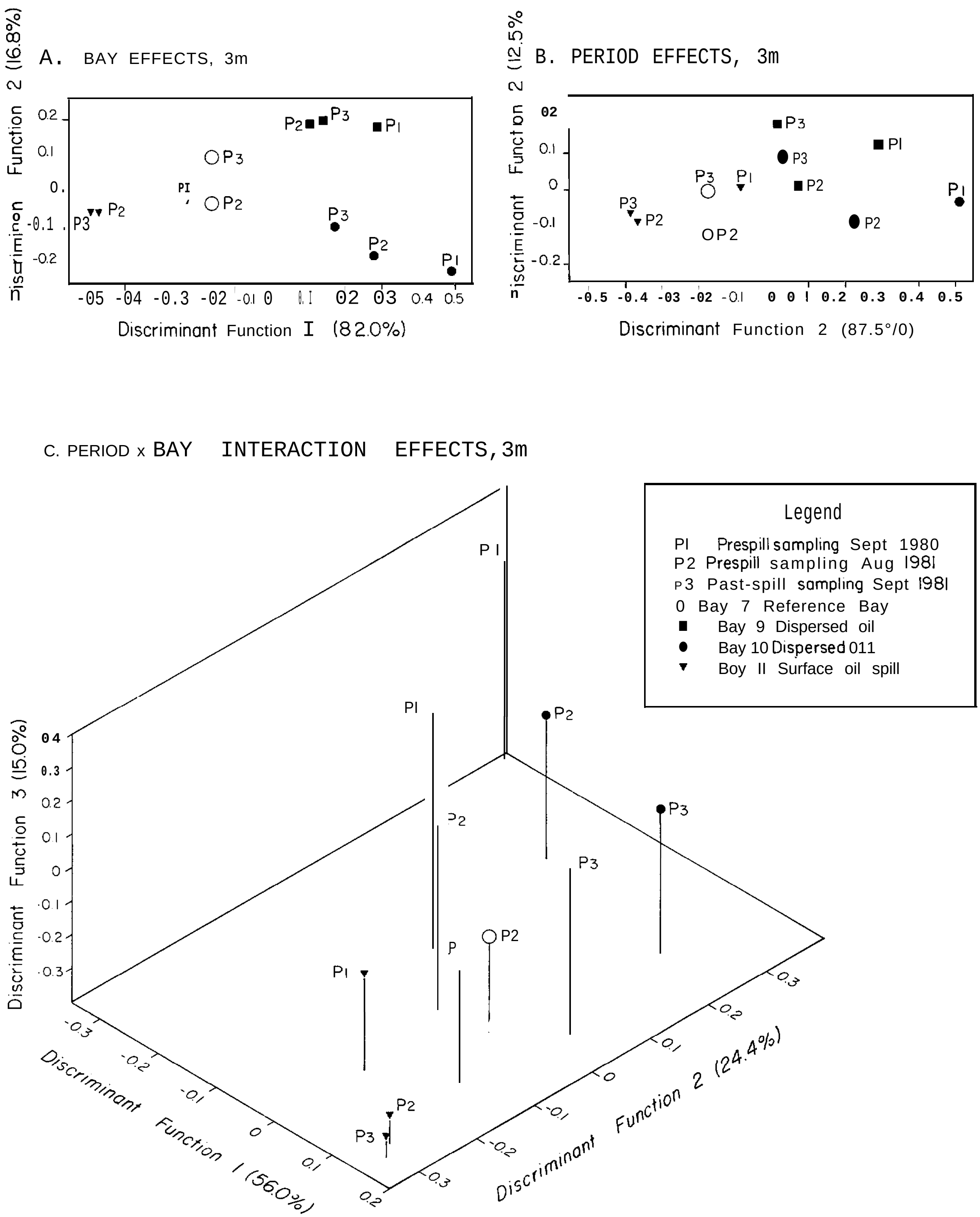

Figure 8. Graphical representation of results of multivariate analysis of variance using data collected at 3 m depth in four bays at Cape Hatt, northern Baffin Island, during September 1980 and August and September 1981. The plots display the results of the tests for main effects and interaction using the transect term as the error term.

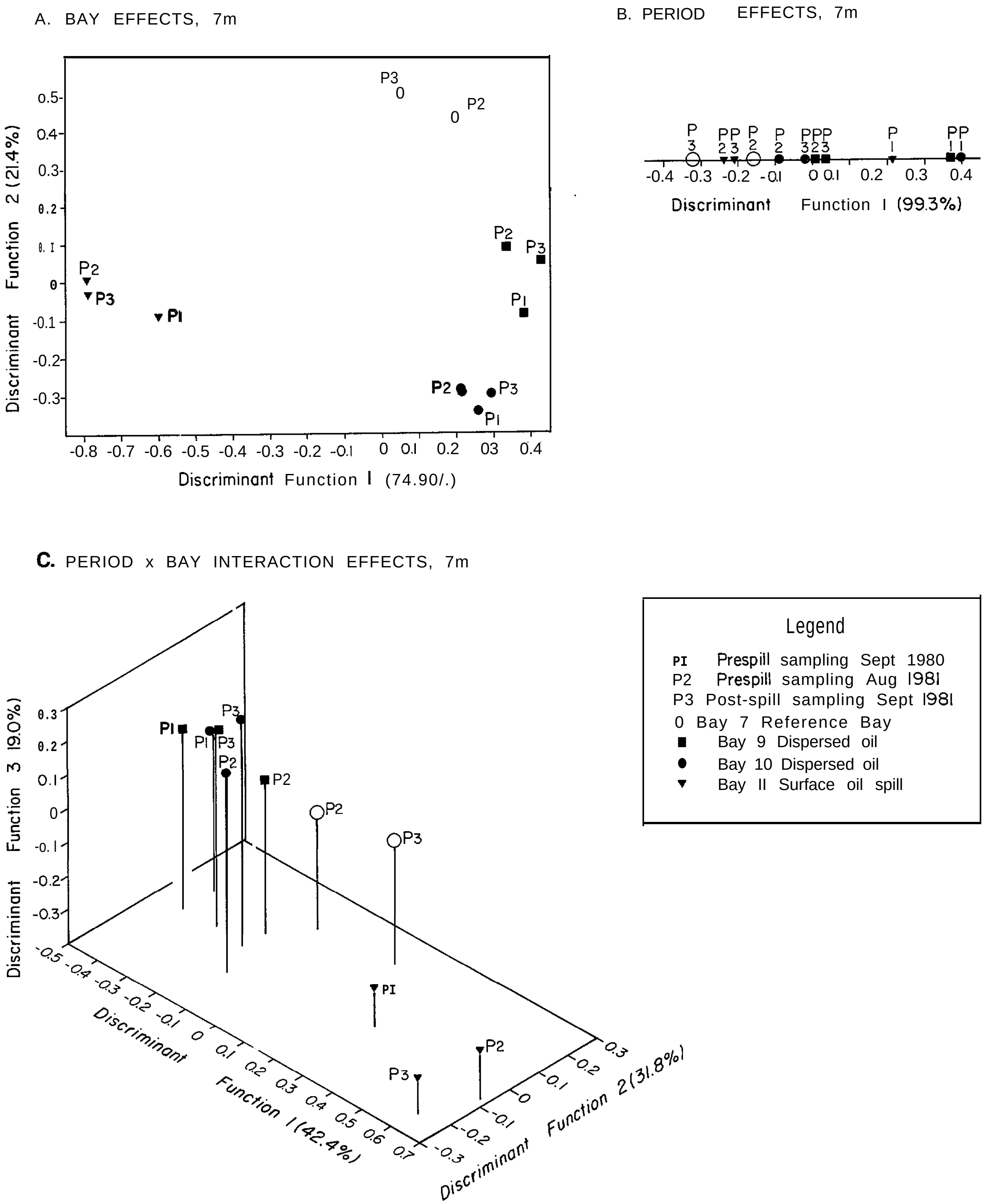

Figure 9. Graphical representation of results of multivariate analysis of variance using data collected at 7 m depth in four bays at Cape Hatt, northern Baffin Island, during September 1980 and August and September 1981. The plots display the results of the tests for main effects and interaction using the transect term as the error term.

group centroids for bay-period combinations are clustered together by bay, with different bays being well separated from one another.

Temporal Effects

At the 7 m depth, temporal variation, i.e. variation among sampling periods, was not significant in either multivariate analysis of variance. Thus at 7 m, community composition was relatively stable over the course of study. However, for technical statistical reasons (limited df) the 3 bay/3 period analysis would only accommodate the first 6 factors, whereas results of the univariate analyses of variance indicate that factor 7 varied significantly with respect to time. This factor represented primarily Mya trucata and Astarte juveniles (Table 12). The temporal variability in this assemblage was apparently annual rather than seasonal (Fig. 7); in general, high positive factor scores occurred in 1980 and negative scores in 1981. This annual difference is also clearly illustrated in Figure 9B. Samples from the 1981 sampling periods are intermingled but distinct from samples taken in 1980. No significant. seasonal differences were evident in the 4 bay/2 period analysis (Table 14).

At 3 m depth, seasonal effects were of marginal overall significance (MANOVA, p = 0.049, Table 14), and are primarily attributable to seasonal variability in the 6th factor, which represents primarily a nemertean and one polychaete. In contrast to the marginal change in community composition evident from August to September 1981, variation among September 1980, August 1981 and September 1981 was highly significant (Table 13). Figure 8B confirms that most of this temporal effect was attributable to annual (1980 vs. 1981) rather than month-to-month differences. The annual variability appears to have been primarily because of changes in abundances of species represented by factor 3 and to a lesser extent factor 6 (Table 13, Fig. 6); factor 3 represents primarily *Astarte* juveniles, Mya *truncata*, two polychaetes and Thyasiridae. This annual effect appears to have been strongest in Bays 9 and 10 (Fig. 6).

Oil Effects

In the present study, which includes temporal and spatial ‘controls’, effects of oil or dispersed oil on community composition would be evident as pre- to post-spill changes in experimental bays that do not occur in the reference bay. The main test of oil effects, the period x bay interaction effect, was not significant in any univariate or multivariate analysis at either depth with either the 3 bay/3 period or the 4 bay/2 period approach (Tables 13 and 14). Thus, effects of oil or dispersed oil on community composition or on dominant species assemblages were not evident in comparisons of data collected 1 year pre-spill, 2-4 weeks pre-spill, and 2-4 weeks post-spill. This absence of detectable community effects is a further reason to be cautious about the interpretation of the two marginally significant period x bay interaction effects for simple biomass and density data (Tables 6 and 7).

The graphical representations of these interaction terms on Figures 8C and 9C show that the relative locations of periods within bays are quite similar among bays, and that the relative locations of bays within periods are similar among periods.

Trophic Relationships

The infaunal animals (excluding gastropod) collected by the airlift sampler were classified into feeding guilds based on data available in the literature (Table 15). The feeding modes follow those described by Fauchald and Jumars (1979).

Filter feeders extract particulate material from the water. Sabellid polychaetes feed externally using a brachial 'fan' whereas bivalves pump water through their mantle cavity and remove particulate material with their gills. Mya truncata burrows deeply in the sediment and extends a siphon to the surface. Mussels (Musculus sp.) are usually attached to rocks or algae and filter material from water entering through a gape in their shell. Many benthic filter feeders ingest material of benthic rather than pelagic origin (Marshall 1970).

Some deposit feeders ingest sand or mud directly from the substrate. These include tube-dwellers (maldanid polychaetes) and polychaetes that burrow through the mud such as Capitella capitata (Fauchald and Jumars 1979). Deposit feeders derive their nutrition from bacteria associated with the organic matter and detritus found in the sediments. The deposit feeders listed in Table 15 generally feed at some depth below the surface of the sediment. The activity of these animals is especially important in reworking the surface layers of the sediment (e.g. Cadée 1979).

Surface deposit feeders feed at the sediment-water interface. Their food includes benthic microalgae and bacteria. Most of the polychaetes

Table 15. Feeding mode of benthic infaunal animals (excluding gastropod) from Cape Hatt, northern Baffin Island. Species only tentatively ass igned to feeding modes are indicated by ?; numbers in parentheses are number of species in that family or group found at Cape Hatt.

	Polychaetes	Bivalves	Others
Filter feeders	Sabellidae (2+) Owenia fusiformis? Chaeopterids (1)	Mya truncata Thyasiridae Astarte spp. (2) Musculus Spp. (2) Hiatella arctica Serripes groenlandicus	Rhizomolgula globularis
Carnivores	Polynoidae (4) Phyllodocidae (4) Pholoe minuta Lumbrineris sp. (1)? Glycera capitata Nephtys ciliata?		Leptasterias Polaris
Deposit feeders	Capitella capitata Cistenides spp. (2) Opheliidae (3) Scoloplos armiger Maldanidae (4) Scalibregma inflatum		Myriotrochus rinkii?
Surface deposit feeders	Chaetozone setosa Terebellidae (3) Ampharetidae (2+) Spionidae (5) Trichobranchus glacialis Diplocirrus sp. (1) Aricidea sp. (1)	Macoma calcarea Macoma moesta? Nuculana minuta	Strongylocentrotus droebachiensis

References for feeding type: Ockelmann 1958; Reid and Reid 1%9; Himmelman and Steele 1971; Ansell and Parulekar 1978; Mohlenberg and Riisgard 1978; Fauchald and Jumars 1979.

included in this group (Table 15) feed by means of tentacles (Fauchald and Jumars 1979). The bivalve Nuculana minuta extends a pair of tentacles or proboscises over the surface of the sediment (Ansell and Parulekar 1978), and the bivalve Macoma calcarea draws in fine particulate material from the sediment surface with the inhalant siphon (Reid and Reid 1969).

The carnivores listed in Table 15 are all motile predators.

An animal's mode of feeding may determine its degree of exposure to oil. A short exposure to dispersed oil may not affect filter feeders as they may stop feeding temporarily. The resultant oil-containing floes that accumulate on the surface of the sediment may, however, seriously affect surface deposit feeders. In active benthic environments, wave action and sediment transport may incorporate undispersed oil into the sediment and seriously affect burrowing deposit feeders.

During all three sampling periods and in all four bays, filter feeding was the dominant feeding mode (Table 16). Biomass of filter feeders at 3 m depth was highest in Bay 9 and lowest in Bay 11 during all periods; at 7 m, biomass of filter feeders was highest in Bay 9 only during Period 1, and was similar in all bays during Periods 2 and 3. In general, there was a trend for biomass of filter feeders to increase from Period 1 to 3 at 3 m depth, and to decrease at 7 m.

Surface deposit feeding was the second most common mode of feeding at 7 m depth in all four bays and in all three periods. Surface deposit feeders were much less abundant at 3 m depth, perhaps owing to instability of the

Table 16. Mean biomass of in faunal animals according to major feeding mode, period, bay and depth. Data are from four bays[1] at Cape Hatt, northern Baffin Island, during September 1980 and August and September 1981[2].

	Period		3 m depth				7 m depth			
			Bay 7	Bay 9	Bay 10	Bay 11	Bay 7	Bay 9	Bay 10	Bay 11
Carnivore	1	g/m^2		12.28	10.21	7.75		14.71	14.71	9.00
		%		2.11	3.44	10.09		0.52	0.94	0.58
	2	g/m^2	12.14	11.67	8.65	10,14	12.84	15.42	73.44	14,41
		%	7.32	1.78	2.62	12.52	1.28	1.01	5.92	1.07
	3	g/m^2	9.53	11.15	17.03	18.49	29.02	11.35	10.37	4.25
		%	4.34	1.29	3.65	23.35	2.29	0.88	0.88	0.35
Filter feeders	1	g/m^2		523.19	256.99	51.58		2613.19	1417.24	1386.34
		%		89.92	86.51	67.15		92.70	90.39	89.53
	2	g/m^2	137.25	587.11	292.30	59.12	707.92	1201.22	1019.59	1224.39
		%	82.75	89.44	88.70	73.01	70.81	78.40	82.12	90.65
	3	g/m^2	190.51	797.46	403.23	46.46	972.26	1107.34	1031.78	1103.60
		%	86.68	91.90	86.51	58.66	76.67	85.56	87.40	91.75
Deposit feeders	1	g/m^2		25.79	19.83	14.20		33.45	32.98	33.18
		%		4.43	6.67	18.48		1.19	2.10	2.14
	2	g/m^2	10.92	28.34	16.15	11.34	23.26	99.25	25.33	21.22
		%	6.59	4.32	4.90	14.00	2.33	6.48	2.04	1.57
	3	g/m^2	9.70	27.17	21.41	11.01	18.35	24.87	26.94	23.90
		%	4.42	3.13	4.59	13.90	1.45	1.92	2.28	1.99
Surface deposit feeders	1	g/m^2		20.55	10.03	3.29		157.56	103.0	119.92
		%		3.53	3.38	4.29		5.59	6.57	7.74
	2	g/m^2	5.55	29.33	12.43	0.38	255.77	216.34	123.25	90.59
		%	3.35	4.47	3.77	0.47	25.58	14.12	9.93	6.71
	3	g/m^2	10.05	31.97	24.47	3.24	248.47	150.6	111.43	71.13
		%	4.57	3.68	5.25	4.09	19.59	11.64	9.44	5.91
Total	1	g/m^2		581.81	297.06	76.82		2818.91	1567.93	1548.44
		%		99.99	100.00	100.01		100.00	100.00	99.99
	2	g/m^2	165.86	656.45	329.52	80.98	999.79	1532.23	1241.61	1350.61
		%	100.01	100.01	99.99	100.00	100.00	100.01	100.01	100.00
	3	g/m^2	219.79	867.75	466.14	79.20	1268.10	1294.16	1180.52	1202.88
		%	100.01	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[1] Bay 7 = reference; Bay 9 = heavy dispersed oil; Bay 10 = light dispersed oil; Bay 11 = surface oil spill.
[2] Period 1 = pre-spill, September 19S0; Period 2 = pre-spill, August 1981; Period 3 = post-spill, September 1981,

sediment surface due to wave action. Again, from Period 1 to 3 there was a trend towards increasing biomass of surface deposit feeders at 3 m depth and decreasing biomass at 7 m depth,

Biomass of carnivores was low and similar among most bays, depths and periods. The unusually high value in Bay 10 at 7 m during Period 2 (73.4 g/m^2) was due to the presence of one relatively large starfish in one sample.

Factors affecting biomass of infaunal feeding types have not been analyzed in the present report; it is doubtful that any significant oil effects would be detected at this time, considering the results of the previous sections. Several trends in the data, however, do indicate possible oil effects: Biomass of surface deposit feeders decreased over the course of the study at 7 m depth in Bay 11 (oil alone), whereas temporal variation in the other bays could be attributable to seasonal factors. Biomass of filter feeders and carnivores increased between August and September at 7 m in the 'control' bay, whereas values in the other bays were constant or decreased slightly. If such trends do indicate effects of oil or dispersed oil, they should be more apparent after the collection of 1-yr post-spill data. Statistical analyses will be applied to these data at that time.

Immediate Post-Spill Oil Effects

Observations of both the oil-only spill and the dispersed oil spill were made by SCUBA divers. Effects on benthic fauna were observed after the dispersed oil spill in Bay 9, and therefore each bay was surveyed on the second post-spill day. Randomly located quantitative photographs were taken and counts of urchins and starfish were made along transects in Bays 9 and 10 on post-spill day 2 and in Bays 7 and 11 on post-spill days 4 and 5, respectively. This section describes immediate oil and dispersed oil effects and presents quantitative data on effects on the bivalve Serripes groenlandicus. Results of urchin and starfish counts are included in the 'Epibenthos' section of this report.

Oil was released on the surface of Bay 11 on 19 August 1981. Observations made by divers during the spill indicated that some oil entered the water column, but it only reached a depth of approximately 1/2 m. On the first post-spill day, many dead and heavily oiled amphipods (Gammarus setosus) were observed at low tide in the intertidal zone, and at the same time some Gammarus were observed to be swimming just below the surface of the water. On 21 August (2 days post-spill) no apparent effects were noted in the benthos at either 3 or 7 m depths, and mysids were active in the water column. Dead fish larvae were observed on the surface just inside the (oiled) booms.

In contrast, the dispersed oil spill produced marked short-term effects on the benthos in Bays 9 and 10. Initial observations during the spill were discontinued due to lack of visibility, and observations were resumed approximately 6 hours after the spill began. At this time visibility was still zero on the 7 m transect; at 3 m oil was still noticeable but visibility was sufficiently good to allow observations. The only effect noted at this time was that burrowing bivalves had emerged onto the sediment surface. A few Mya truncata and Macoma sp. and numerous Serripes groenlandicus were observed (see quantitative data, below). Some Serripes were gaping and making erratic movements with their extended feet. No surfaced bivalves were observed in Bays 7 or 10 immediately after the observations were made in Bay 9.

On the following two days observations were made again, in Bays 9 and 10 (approximately 24 and 48 hours post-spill), and in Bays 7 and 11 (approximately 48 hours post-spill). No effects were noted in Bays 7 or 11, but effects were apparent at both 3 m and 7 m in both dispersed-oil bays. In Bay 9, these effects were more extensive that on the previous day. Benthos affected included bivalves (Mya, Astarte, Macoma and Serripes), large errant polychaetes (Phyllodoce), ophiuroids, asteroids, holothuroids, urchins, gastropod (including limpets), sipunculids and fish. Bivalves and polychaetes that normally burrow were on the sediment surface and many bivalves were gaping. Fish were moving more slowly than usual, and the echinoderms and gastropods were lying on the substrate in unnatural positions (e.g., upside-down). Some individuals of each invertebrate group responded unusually slowly when prodded, and others did not respond. On the second post-spill day (when photographs were taken) many Serripes were still on the substrate, and some were observed to be attempting to rebury themselves.

Density and biomass of Serripes on the sediment surface in the dispersed oil bays (estimated from randomly located quantitative photographs), together with density and biomass estimates of S. groenlandicus in the sediment before and after the spill (based on airlift samples), are shown in Table 17. Biomass estimates were derived from measurements of surfaced Serripes in photographs. Measurements were converted to weights using whole wet weight-length relationships calculated for the same animals as were used in dry meat

Table 17. Comparison of density and biomass estimates of Serripes groenlandicus in the substrate (based on airlift samples) and on the substrate surface (based on photographs) in two study bays[1] at Cape Hatt, northern BSf fin Islam?, during August and September 1981[2]. DSta shown are mean ± SD; baaed on 23 or 24 airlift samples (total of 1.5 m^2) and 17 to 31 photographs (total of 4.25 to 7.75 m^2) for each bay/depth/date combination.

		Density (no./m^2)				Biomass (g/m^2)			
		Bsy9		Bay 10		Bsy 9		Bay 10	
Depth	Date(s)[2]	Subsurface	Surface	Subsurface	Surface	Subsurface	Surface[3]	Subsurface	Surface[3]
3m	6-17 Aug.	28.0 ± 50.7	0	0	0	26.8 ± 48.2	0	0	0
	29 Aug.		7.8 ± 9.1		1.9 * 3.1		27.2 * 44.1		15.3 * 26.8
	1-7 Sept.	15.3 * 19.2	2.5 * 6.6	0.7 * 3.3	0	21.8 * 57.6	9.6 * 27.0	0.2 ± 0.9	0
7 m	6-17 Aug.	50.0 * 42.3	0.9 * 1.7	25.7 * 24.9	13.3 * 1.0	281.6 * 288.6	5.6 * 11.4	157.5 * 183.7	1.6 ± 6.3
	29 Aug.		18.1 * 13.9		9.3 * 7.1	–	106.8 ± 88.9	-	67.5 ± 53.6
	1-7 Sept.	45.3 ± 37.3	9.7 ± 6.3	20.7 ± 20.3	2.3 * 3.4	197.1 * 178.4	66.7 * 46.0	80.5 * 118.8	18.0 * 28.1

[1] Bay 9 = heavy dispersed oil; Bay 10 = light dispersed oil.
[2] 6-17 August = pre-spill; 29 August = second day following dispersed oil spill; 1-7 September = pint-spill.
[3] Surface biomass estimates are minimum estimates (see text).

weight-length analyses. These relationships (Period 2 and 3 data combined) were weight = 0.1689 length $^{2.9329}$ (r = 0.99, n = 88) in Bay 9, and weight = 0.1694 length $^{2.9380}$ (r = 0.98, n = 34) in Bay 10. The resulting biomass estimates are underestimates because size was underestimated for all individuals except those lying exactly perpendicular to the camera lens. When their orientations varied too far from the perpendicular, individuals were not measured, but were assigned the average of the estimated individual biomasses at a given depth and bay. These average values were used, together with biomass estimates for measured individuals, in the calculation of mean $\pm$ SD biomass/m^2; hence standard deviations are also underestimated.

In the pre- and post-spill systematic sampling periods, Serripes was relatively abundant in the sediment at 7 m in all four bays, and at 3 m in Bay 9. Very few Serripes were observed on the sediment surface at any time in Bays 7 or 11. Similarly, none or very few were photographed on the surface in the pre-spill period in Bays 9 and 10. On the second post-spill day, however, numerous Serripes were photographed on the sediment surface in the dispersed-oil bays. At that time in Bays 9 and 10 at 7 m depth, Serripes on the sediment surface represented approximately 36% of pre-spill subsurface densities, and a similar proportion of subsurface biomasses (approximately 38 and 43% in Bays 9 and 10, respectively). In Bay 9 at 3 m depth, 28% of the pre-spill Serripes surfaced, but in this case the proportion in terms of biomass was much higher (approximately 100%; Table 17). In Bay 10 at 3 m depth, a few large Serripes were on the sediment surface following the spill (1.9 ind./m^2; 15.3 g/m^2); the difference between densities on the surface then and under the surface in August (0) and in September (0.7 $\pm$ 3.3 ind./m^2) is likely attributable to sampling error. The distribution of Serripes was patchy (SD >> mean in the data above), and a much larger area was covered by photographs than by airlifts (Table 17).

Comparisons of surface and subsurface biomass data must, however, be interpreted with caution. As previously mentioned, surface biomass was underestimated; hence the proportion of Serripes biomass which came to the sediment surface in response to the dispersed oil was higher than is evident in Table 17. A higher proportion of biomass than of numbers implies a difference in size structure between subsurface and surfaced populations; this difference is also evident in Figure 10, which shows length-frequency histograms for subsurface animals collected by airlift in Periods 1, 2 and 3 and for surfaced animals measured in photographs. Any comparisons involving larger individuals (including mean sizes) are not warranted because of the bias in the airlift data (see 'Size-Frequency Distribution'); smaller individuals, however, are well represented in both surface and subsurface data, and marked differences between the two types of data are apparent. Individuals <10 mm in length were not recorded on the substrate surface and yet were common in airlift samples; the bimodality apparent in subsurface populations in each sampling period did not occur in the Serripes on the sediment surface (Fig. 10). Younger individuals are generally more susceptible to the effects of oil (e.g. Rice et al. 1975), and it is possible that the smaller Serripes were killed outright or affected to the extent that they were unable to leave the substrate.

Numbers of Serripes on the surface decreased with time after the spill in all cases: At 7 m in Bay 9, the number at the surface, relative to the subsurface number in August, was 36% on the 2nd post-spill day, but only 19%

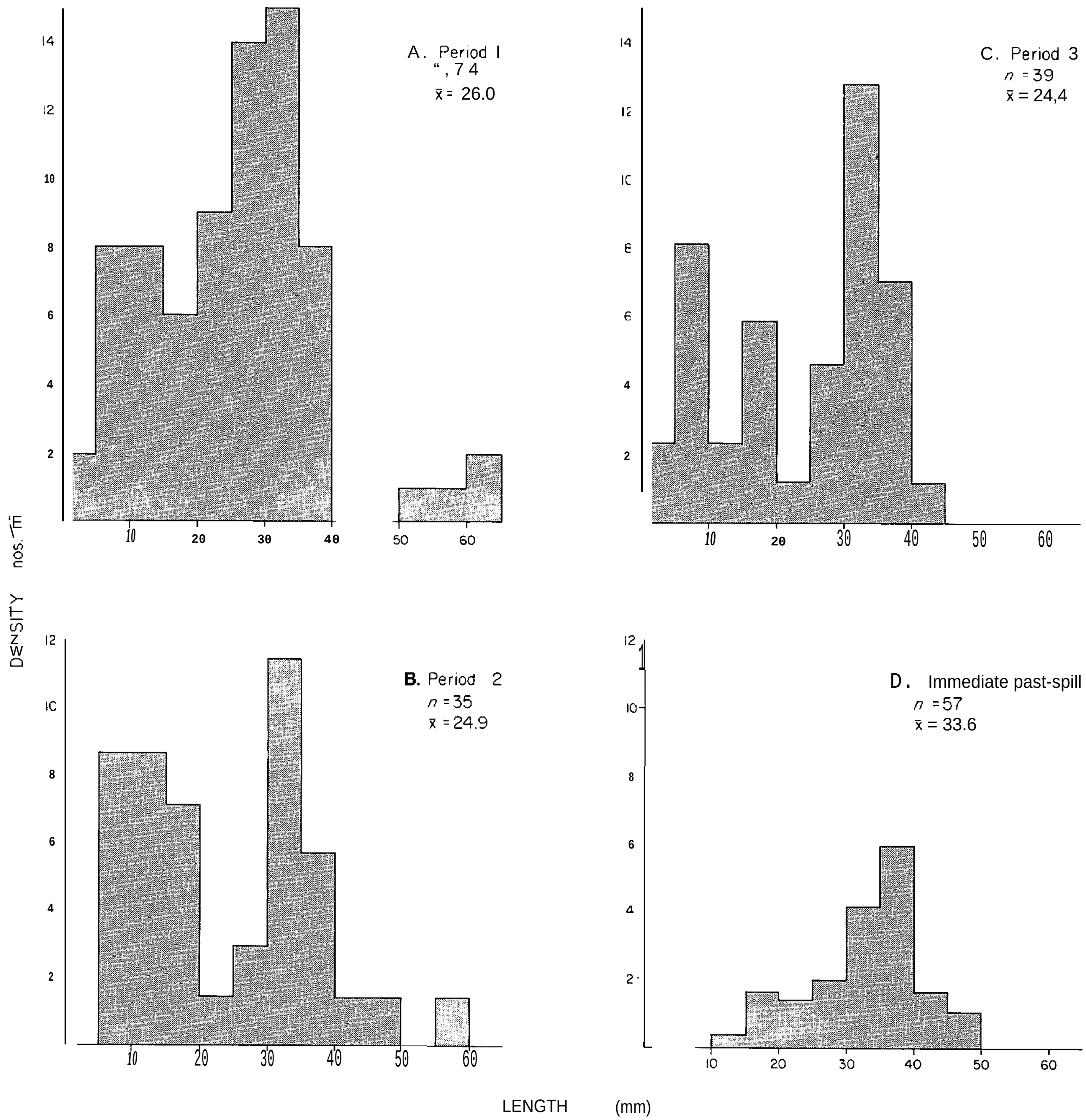

Figure 10. Length-frequency histograms for Serripes groenlandicus in the substrate and on the substrate surface at 7 m depth in Bay 9 immediately following the dispersed oil spill at-Cape Hatt, northern Baffin Island. All but (D) are based on individuals collected in airlift samples; (D) is based on measurements from photographs.

on the 7th post-spill day. At 3 m in Bay 9, the proportion at the surface was 28% on day 2 and 9% on day 9. At 7 m in Bay 10, 36% were at the surface on day 2 but only 9% were still on the surface on the 10th post-spill day, None of the few animals on the surface on the 2nd day at 3 m in Bay 10 were present on the 10th day. It is uncertain whether differences between bays and depths reflect differences in the length of time after the spill, or different levels of dispersed oil. Bay 10 received oil levels approximately an order of magnitude less than did Bay 9, and also had the higher decrease in densities of Serripes on the surface.

These decreases in the densities of surfaced Serripes in the 10 days following the spill may indicate removal by predators, Sub-surface densities decreased from August to September at both depths in Bay 9 and at 7 m in Bay 10, approximately in proportion to the number of Serripes that had surfaced (Table 17). Also, some Serripes may have recovered and reburied themselves in the sediment (see observations above).

It is likely that the quantitative data from airlift samples presented in this report do not reflect any of the observed effects on invertebrates because the first post-spill sampling period was too soon after the spill itself. Animals killed by the oil would be indistinguishable from live animals in the September 1981 airlift samples. However, any dead animals will have decomposed or been consumed before the next sampling period in August 1982, and any pronounced effects will then become evident.

Epibenthos

For the purposes of the present study, the term 'epibenthos' refers to motile members of the benthic community, We include those animals capable of rapid movement through the lower part of the water column (e.g. crustaceans) . We also include those that move relatively slowly on the sediment surface, but are capable of covering relatively large distances because of their size (e.g. urchins, starfish). As previously mentioned, the purpose of this definition is to facilitate the interpretation of any changes in faunal densities in the study bays after oiling. In the cases of the above animals, it will not be possible to distinguish with certainty the relative roles of mortality and emigration in determining any changes in densities. Hence relatively little effort is directed to the analysis of the distributions of epibenthic animals. A further justification for the inclusion of urchins and starfish in this section is the fact that sampling methods applied to these large and sparsely distributed animals were different and less intensive than those applied to the infauna.

Crustaceans

The available data on highly motile epibenthic crustaceans at Cape Hatt are from the same airlift samples upon which infaunal results are based. Estimates for epibenthic crustaceans likely are not as accurate as those for infauna, however, due both to escape of organisms from the area sampled and to inclusion of those inadvertently drawn into the airlift from outside the 0.0625 m2 sampling area. A modification to the sampler, developed for EAMES studies to overcome this shortcoming (see Thomson and Cross 1980), was not practical in the present study because of difficulties in operating the airlift in the mixed sediment-rock substrate. No quantitative estimates are available for the extent to which epibenthic crustaceans were over- or under-estimated in the present study.

Epibenthic crustaceans collected in airlift samples consisted entirely of ostracods (56.3-69.2%, depending on period), amphipods (22.2-34.0%) and cumaceans (8.0-9.6%). Ostracods, six species of amphipods, and two species of cumaceans accounted for 86.6 to 89.0% of total numbers, and 72.9 to 82.4% of total biomass, depending on period (Table 18). All of these species are common in nearshore high arctic waters (Sekerak et al. 1976; Buchanan et al. 1977; Thomson and Cross 1980).

Mean densities of major taxa and dominant species of epibenthic crustaceans are shown by period, bay and depth in Table 19. Densities of ostracods, all cumaceans and the cumacean Lamprops fuscata were considerably higher in most bay/period combinations at the 7 m depth than at 3 m. Densities of amphipods were more similar at the two depths, although a tendency toward higher numbers at the 7 m depth was evident, both for total amphipods and for the individual species included in Table 19. Differences among periods and bays were also apparent for most taxa considered. Differences among periods within bays were usually small and not consistent among bays (Table 19).

There was no evidence of mass emigration or mortality in the experimental bays. Densities did decrease substantially between August and September 1981 for some epibenthic taxa (e.g., Lamprops fuscata, 3 m, Bay

Table 18. Percent contribution of 10 dominant crustaceans to total epibenthic biomass and density in the study bays at Cape Hatt, northern Baffin Island, during September 1980 and August and September 1981[1]. Based on 524 airlift samples, each covering 0.0625 m^2, from 3 and 7 m depths.

Taxon	% of total density			% of total biomass (wet weight)		
	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3
Ostracoda (Myodocopa)	54.85	69.08	64.78	27.64	37.88	31.92
Anonyx nugax (A)	7.41	0.61	1.16	47.06	25.80	29.56
Guernea sp. (A)	7.00	7.77	8.48	0.71	1.44	1.23
Lamprops fuscata (C)	6.66	4.92	4.68	0.86	1.34	1.29
Paroediceros lynceus (A)	2.49	0.82	0.89	3.04	3.17	3.58
Monoculodes borealis (A)	2.05	0.73	0.60	0.92	0.54	0.60
Pontoporeia femorata (A)	1.50	2.31	2.51	1.54	6.0	6.42
Ostracoda (Podocopa)	1.44	0.12	1.94	0.11	0.05	0.31
Brachydiastylis resima (C)	1.31	1.43	0.93	0.29	0.68	0.38
Stenothoidae sp. (A)	1.84	1.21	1.78	0.25	0.46	0.33
Total	86.55	89.00	87.75	82.42	77.36	72.92
Total epibenthos	1152.1 (ind./m^2)	1262.1 (ind./m^2)	1337.9 (ind./m^2)	(g;;:)	(g;;;)	4.8 (g/m^2)

(A) = amphipod, (C) cumacean.

[1] Period 1 = pre-spill, September 1980; Period 2 = pre-spill, August 1981; Period 3 = post-spill, September 1981.

Table 19. Mean density (no./m[2]) of major taxa and dominant species of epibenthic crustaceans in four bays[1] at Cape Hatt, northern Baffin Island, during September 1980 and August and September 1981[2]. Data are expressed as mean ± standard deviation and are based cm 23-24 replicate 0.0625 m^2 airlift samples from each period/bay/depth combination.

Taxa	Period	3 m Depth				7 m Depth			
		Bay 7	Bay 9	Bay 10	Bay 11	Bay 7	Bay 9	Bay 10	Bay 11
Ostracoda	1		42.7 ± 46.1	44.7 ± 101.6	9.3 ± 14.1		966.0 ± 735.5	1728.7 ± 84.8.7	1113.3 ± 723.6
	2	9.3 ± 19.4	28.7 ± 49.5	12.5 ± 15.2	2.7 ± 7.7	2045.3 ± 990.8	1720.7 ± 733.1	1543.7 ± 620.3	1616.7 ± 1964.8
	3	10.0 ± 15.5	223.3 ± 500.8	19.5 ± 38.2	5.6 ± 12.4	2236.7 ± 675.5	1819.3 ± 1208.9	1763.6 ± 771.0	1074.0 ± 884.5
Amphipoda	1		222.7 ± 141.5	344.0 ± 268.6	2s6.0 * 180.7		269.3 * 244.7	642.0 ± 366.8	583.3 ± 296.9
	2	171.3 * 108.4	246.0 ± 361.0	245.9 * 228.9	216.8 * 274.4	336.6 ± 199.0	289.3 * 156.8	258.1 ± 97.7	471.3 * 386.6
	3	218.7 ± 162.9	463.3 ± 447.8	292.0 * 295.5	263.2 ± 307.4	334.7 ± 157.4	251.3 ± 106.5	387.0 ± 179.4	457.5 ± 234.9
Anonyx nugax	1		4.0 ± 8.5	12.7 ± 39.7	24.0 * 84.3		86.0 ± 221.3	296.0 ± 309.0	90.0 * 81.3
	2	2.0 * 5.4	2.0 ± 7.2	0	3.3 * 10.5	3.3 ± " 8. I	20.7 ± 46.8	8.3 ± 12.6	21.3 ± 26.6
	3	10.7 * 17.4	2.7 * 6. 1	0.7 ± 3.3	0.7 * 3.3	30.0 ± 62.6	6.7 * 10.5	32.0 ± 33.4	41.4 * 40.6
Guernea sp.	1		72.0 ± 63.8	41.3 * 63.3	14.0 * 25.5		91.3 * 64.6	112.7 * 78.9	152.0 ± 97.0
	2	12.7 * 17.0	96.7 * 122.4	47.2 * 32.4	10.7 * 18.7	116.7 * 48.9	172.7 * 110.0	119.7 * 70.2	207.3 ± 192.3
	3	36.7 ± 47.8	206.6 * 143.4	76.7 * 81.7	12.5 ± 15.2	95.3 * 67.5	148.0 ± 76.8	185.3 * 105.2	144.0 ± 86.3
Paroediceros lynceus	1		4.7 ± 11.0	34.0 * 72.4	11.3 * 13.7		4.7 * 10.0	41.3 ● 47.2	76.0 ± 92.1
	2	2.7 * 6.1	1.3 * 4.5	18.1 ± 25.7	19.3 * 35.0	4.7 * 8.8	3.3 * 8.1	13.9 * 12.1	19.3 * 27.9
	3	3.3 ± 9.4	2.7 ± 7.7	30.0 ± 42.3	13.6 ± 34.2	2.0 * 7.2	3.3 * 8.1	9.3 * 11.5	32.0 ± 32.4
Cumacea	1		26.7 ± 36.4	36.7 * 84.5	10.7 ± 27.8		142.0 ± 110.0	136.0 ± 94.8	308.7 ± 162.7
	2	19.3 ± 30.9	139.3 ± 375.9	20.1 ± 31.1	24.0 ± 46.7	102.0 ± 85.3	122.7 ± 85.3	111.3 ± 93.7	330.0 ± 372.9
	3	35.3 * 41.7	90.0 * 93.3	115.3 ●178.0	11.8 ± 20.0	72.0 * 78.1	175.3 ± 109 0	133.8 * 74.2	223.7 ± 164.0
Lamprops fuscata	1		24.0 ± 36.2	22.7 ± 62.4	10.7 ± 27.8		108.7 ± 98.4	110.0 ± 8$.0	184.0 ± 137.5
	2	18.7 * 30.8	138.0 ± 376.4	20.1 * 31.1	22.7 * 46.4	57.3 ± 61.9	82.7 * 91.9	39.7 ± 34.7	114.7 * 133.1
	3	34.0 ± 41.2	87.3 ± 91.1	114.72176.9	4.2 ± 8.7	24.7 ± 29.5	115.3 ± 75.2	28.7 ± 25.8	90.8 * 82.3

[1] Bay 7 = reference; Bay 9 = heavy dispersed oil; Bay 10 = light dispersed oil; Bay 11 = surface oil spill.
[2] Period 1 = pre-spill, September 1980; Period 2 = pre-spill, August 1981; Period 3 = pst-spill, September 1981.

11), but densities increased between these two periods for other taxa (e. g., Ostracods, 3 m, Bay 9). Overall, there was a trend towards increases in density from August to September 1981 at the 3 m depth (increases for 22 of 28 taxon-bay combinations), and no apparent trend at the 7 m depth (increases for 12 of 28 cases). For reasons outlined above, no statistical treatment of the distribution of epibenthic crustaceans is presented.

Echinoderms

The urchin Strongylocentrotus droebachiensis is widely distributed and often relatively abundant (up to 14 individuals/m^2) in the Lancaster Sound area, whereas the distribution of the starfish Leptasterias polaris is more restricted (Thomson and Cross 1980). Both species are of interest because of their trophic positions. Strongylocentrotus droebachiensis is a herbivore whose impact on benthic algal populations has been found to be considerable on both the east and west coasts of Canada (Miller and Mann 1973; Foreman 1977). L. polaris is a top predator feeding primarily on large bivalves, and hence may be affected indirectly by oil through changes in bivalve populations. Thus, in spite of the above-mentioned interpretational difficulties caused by the mobility of these animals, the densities of urchins and starfish are being monitored carefully throughout the course of this study. Too few urchins or starfish were present at the 3 m depth in the study bays to warrant discussion.

Densities of S. droebachiensis and L. polaris at the 7 m depth in the study bays during each period, and immediately (2 to 4 days) after the dispersed oil spill, are shown in Table 20. ANOVA results for 3 bay/4 period

Table 20. Densities of urchins (Strongylocentrotus droebachiensis) and starfish (Leptasterias polaris) at 7 m depth in the study bays[1] at Cape Hatt, northern Baffin Island, during 2 pre-spill and 2 post-spill sampling periods[2]. Data are based on 15 in situ counts, each covering 10 m^2, in each period-bay combinat ion.

		Bay 7		Bay 9		Bay 10		Bay 11	
Species	Period	Date[3]	Mean * SD	Date[3]	Mean * SD	Date[3]	Mean * SD	Date[3]	Mean ± SD
Urchin (no./#)	1			30/8	4.4 ±1.5	13/9	1.6 ± 0.7	12/9	1.0 * ().4
	2	15/8	10.0 * 3.4	6/8	7.6 * 2.2	13/8	1.9 * 0.9	10/8	1.3 * 0.5
	*	31/8	8.6 ± 2.2	29/8	2.9 ±1.1	29/8	3.0 ± 1.1		
	3	2/9	7.8 ±3.5	3/9	5.5 ± 2,8	6/9	2.3 * 0.7	1/9	1.3 ± 0.7
Starfish (no./lo m^2)	1			30/8	1.0 * 1.1	13/9	1.9 * 1.3	12/9	0.7 ± 1.1
	2	15/8	3.3 ± 2.5	6/8	1.1 ± 0.9	13/8	1.3 ± 0.9	10/8	0.5 ± o.8
	*	31/8	5.8 * 3.7	29/8	1.1 *1.5	29/8	2.3 ± 1.5		
	3	2/9	4,5 ±3.3	3/9	1.9 ± 1.2	6/9	2.7 ± 1.8	1/9	1.6 ± 2.0

[1] Bay 7 = reference; Bay 9 = heavy dispersed oil; Bay 10 = light dispersed oil; Bay 11 = surface oil spill.
[2] Period 1 = pre-spill, September 1980; Period 2 = pre-spill, August 1981; * = 2 days after dispersed oil spill; Period 3 = post-spill, September 1981.
[3] Dates shown are day and month for 1980 (Period 1) or 1981 (other periods).

and 4 bay/3 period analyses, based on log-transformed data, are given in Table 21. In these analyses, the 2-4 day post-spill data are treated as an additional period. Unfortunately, there is an empty cell for 2-4 day post-spill/undispersed oil in both of these analyses.

Differences among transects were not significant for either species in either type of analysis. Among-bay differences, on the other hand, were significant for both species in both analyses. Strongylocentrotus droebachiensis was more common in Bays 7 and 9 than in Bays 10 or 11. Leptasterias polaris was most abundant in Bay 7, and occurred at a relatively low and similar abundance in Bays 9, 10 and 11 (Table 20). Temporal differences were also significant for L. polaris: densities increased in all four bays between pre- and post-spill sampling periods.

The significance of the bay x period interaction effect for S. droebachiensis (Table 21) and inspection of the data (Table 20, Figure 11) indicate an effect of the dispersed oil spill. From mid August to early September, densities were constant in Bay 11 (oil alone), and decreased slightly in Bay 7 ('control'). In the dispersed oil spill bay (Bay 9), however, urchin density at 7 m depth decreased markedly immediately after the spill and increased again within a week of the spill. In Bay 10, which received dispersed oil in concentrations approximately an order of magnitude lower than those in Bay 9, urchin density at 7 m depth increased immediately after the spill and then decreased approximately one week later. Few dead or immobilized urchins were observed after the spill; hence urchins must have emigrated from the spill bay, likely moving to deeper, uncontaminated water. The post-spill increase in urchin density following the spill in Bay 10 is

Table 21. Three-factor analyses of variance (ANOVA) for densities[1] of urchins and starfish at 7 m depth in the study bays at Cape Hatt, northern Baffin Island, during two pre-spill (September 1980, August 1981) and two post-spill (August, September 1981) periods. F-values are shown together with significance levels (ns = $P > 0.05$; * $P \leq 0.05$; ** $P \leq 0.01$, *** $P \leq 0.001$).

Species	Analysis	Source of Variation and df[2]				
		Period 3(2) ,22	Bay 2(3) ,22	Period x Bay 5(5) ,22	Transect (Bay) 6(8),132	Per x Trans (Bay) 16(14),132
<u>Strongylocentrotus droebachiensis</u>	3 bay/4 period[3]	4.62 *	134.47 ***	9.07 ***	0.% ns	0.98 ns
	4 bay/3 period[4]	3.26 ns	150.27 ***	9.20 ***	1.56 ns	0.63 ns
<u>Leptasterias polaris</u>	3 bay/4 period[3]	6.69 **	14.80 ***	0.63 ns	2.15 ns	0.60 ns
	4 bay/3 period[4]	7.87 **	23.19 ***	1.22 ns	1.18 ns	1.19 ns

[1] Based on log-transformed *in situ* counts within five 1 x 10 m areas on each of three transects in each bay and period. See Table 20 for a summary of the data.

[2] Numerator df are shown for 3 bay/4 period analysis, followed by 4 bay/3 period analysis (in parentheses).

[3] Bays 9 (heavy dispersed oil), 10 (light dispersed oil) and 11 (surface oil spill); Periods 1 (pre-spill, September 1980), 2 (p-e-spill, August 1981), * (2 days after dispersed oil spill, August 1981) and 3 (post-spill, September 1981).

[4] BSys 7 (reference), 9, 10 and 11; Periods 2, * and 3.

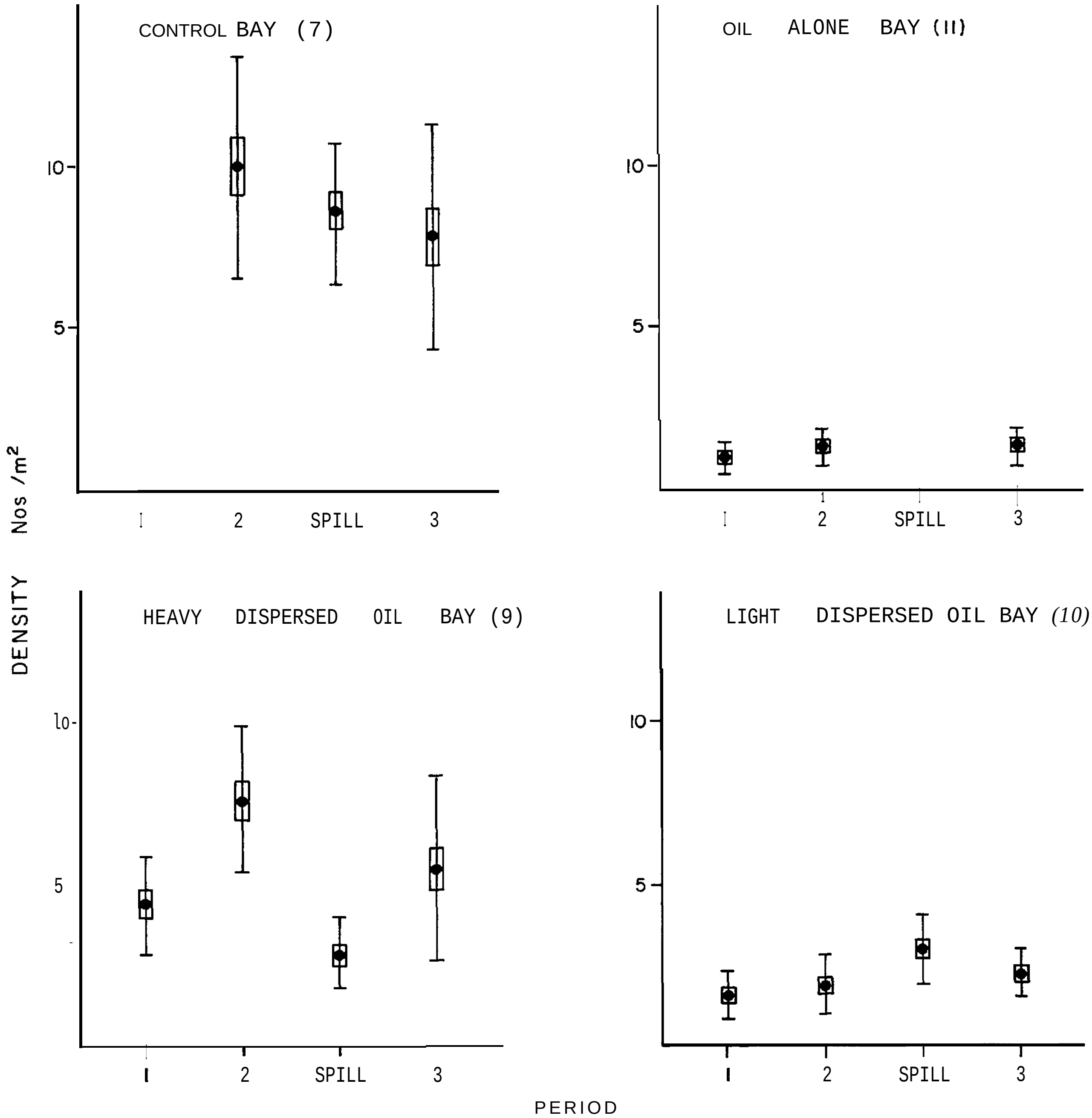

Figure 11. Mean density of the urchin Strongylocentrotus droebachiensis in four bays at Cape Hatt, northern Baffin Island, during September 1980 (Period 1) and August and September 1981 (Periods 2 and 3). Data for 'spill' period were collected 2-4 days following the dispersed oil spill. All data are based on 15 in situ counts (1 x 10 m area) at 7 m depth in each bay and period; no data were collected in Bay 7 Period 1 or in Bay 11 immediately following the spill. Vertical lines are ± SD and boxes are ± SE.

less easy to interpret. Dispersed oil entered Bay 10 at a depth of approximately 8-10 m and this may have caused a movement from deep to shallow water. These data for S. droebachiensis, combined with observations of effects on urchins and starfish made during and after the dispersed oil spill (see previous section), indicate that dispersed oil does have an effect, but that recovery is likely. Longer term effects cannot be assessed until after the 1982 field season.

Macrophytic Algae

The benthic marine algae of the North American Arctic have been studied intermittently since the early nineteenth century, but early reports consisted of little more than species lists (Kent 1972). Recently, floristic and ecological studies have been performed in Labrador and Ungava Bay (Wilce 1959), West Greenland (Wilce 1964), Prince Patrick Island (Lee 1966), Pangnirtung Fiord (Kent 1972), and in several areas in the northern and southwestern Canadian Arctic (Lee 1980). These studies have shown that macrophytic algae are a common feature of arctic and subarctic nearshore waters, both on exposed rocky coasts and on soft bottoms. In the latter case, the algae are either loose-lying and still viable or are attached to mud, small rocks, shells and polychaete tubes (Lee 1966; Lee 1973, 1980). These floristic studies have provided much valuable information on species composition, zonation and reproduction of littoral and sublittoral macrophytes in high latitudes. Quantitative studies of kelps and conspicuous understory algae have also been carried out at several locations in the Lancaster Sound area (Thomson and Cross 1980), but to date combined floristic/biomass studies of benthic macroalgae have not been reported for the Canadian Arctic.

The overall effects of oil on macroalgal communities have not been studied in the Arctic, but Hsiao et al. (1978) determined that *in situ* primary production in two macroalgal species in the Beaufort Sea was significantly inhibited by all types and concentrations of oil tested. In other latitudes, studies of the effects of oil spills with and without the use of chemical dispersants have often demonstrated changes in the abundance of littoral and sublittoral macrophytic algae (see Natural Academy of Sciences 1975, Table 4-l). In some cases widespread mortality has been observed (e.g. Bellamy et al. 1967; Thomas 1973), whereas in other cases no mortality was apparent immediately following the spill (e.g. Nelson-Smith 1968). Subsequent changes following spills have included a proliferation of macroalgal growth, which has been attributed to the oil-related absence of herbivores including sea urchins (North et al. 1965) and limpets (Nelson-Smith 1968).

Species Composition

A total of 47 species of macroalgae were collected in the study bays at Cape Hatt (Table 22). This is a relatively small number when compared with the 126 species known in the arctic sublittoral (Wilce 1973) or the 183 arctic species and varieties (littoral and sublittoral) recorded by Lee (1980). This difference undoubtedly is largely attributable to the small area and relatively homogeneous substrate type studied at Cape Hatt relative to the wide geographical coverage and diversity of substrate types included in the above investigations.

The dominant species at 3 m in the study bays were *Stictyosiphon tortilis*, *Pilayella littoralis* and *Dictyosiphon foeniculaceus*. Together with

Table 22. Species list of macro phytic algae collected in four bays at Cape Hatt, northern Baffin Island, during August and September 1980 and 1981.

Species and Authority	
Chlorophyceae	Chorda f ilum (Linnaeus) Lamouroux
Ulothrix flacca (Dilwyn) Thuret in LeJol is	Chords tomentosa Lyngbye
Blidingia minima (Nägeli ex Kützing) Kylin	Agarum cribrosum (Mertens) Bory
Chlorochytrium schmitzii Rosenvinge	Lmninaria saccharina (L.) Lamouroux
Chlorochytrium dermatocolax Reinke	Laminaria solidungula J. Agardh
Spongomorpha sonderi Kützing	Laminaria long icruris Pyl.
S pongomorpha s p.	Haplospora globosa Kjellman
Chaetomorpha linum (O. F. Müller) Küt zing	Sphacelaria plumosa Lyngbye
Chaetomorpha melagonium (Weber et Mohr) Kützing	Sphacelaria arct ica Harvey
	Sphacelaria caespitula Lyngbye
Phaeophyceae	Fucus distichus L. subsp. evanescens (C. Ag.) Powell
Pilayella littorals (L.) Kjellman	
Myriactula lubrica (Rupr.) Jaasund	Rhodopbyceae
Symphyocarpus strangulans Rosenvinge	Audouinella purpurea (Lightfoot) Woelkerl ing
Eudesme virescens (Carmichael) J. Agardh	Ahnfeltia plicata (Hudson) Fries
Phaeostroma pustulosum Kuckuck	Neodilsea integra (Kjellman) A. Zinova
Phaeostroma parasiticum Børgesen	Halosaccion ramentaceum (L.) J. Agardh
Phaeostroma sp.	Palmaria palmata (L.) O. Kuntze
Elachistea lubrica Ruprecht	Polysiphonia arctica J. Agardb
St ict yosiphon tort ilis (Ruprecht) Re inke	Rhodomela con fervoides (Hudson) Silva f. flagellaris Kjellman
Platysiphon verticillatus Wilce	Phyllophora truncata (Pall as) A. Zinova
Omphalophyllum ulvaceum Rosenvinge	Ptilota serrata Kützing
Chordaria flagelliformis (0. F. Müller) C. Agardh	Odonthalia dentata (L.) Lyngbye
Delamarea attenuata (Kjellman) Rosenvinge	
Diet yosiphon foeniculaceus (Hudson) Grevil le	Chrysophyceae
Desmarestia aculeata (L.) Lamouroux	Phaeosaccion collinsii Farlow
Desmarestia viridis (0. F. Müller) Lamouroux	
Punctaria glacialis Rosenvinge	

tubular diatoms (it was impractical to separate these from P. littorals), these species comprised 77,2% of total macroalgal biomass when all bays and periods were combined. These species formed the lower algal stratum--the under story. The understory also included Sphacelaria Spp. (primarily S. arctica and S. plumosa), Chaetomorpha linum and C. melagonium, which together comprised 3.8% of macroalgal biomass, and a number of other species that were not weighed separately (3.1% of biomass). The biomasses of most of the dominant understory species were similar in the various bays (Table 23).

The dominant canopy species at 3 m were Neodilsea integra (6.8% of total biomass), Fucus distichus (4.0%), Laminaria spp. (3.0%) and Chorda spp. (1.3%). Other less abundant canopy species were Halosaccion ramentaceum, Rhodomela confervoides, Punctaria glaciale and Desmarestia Spp., which together comprised less than 1% of macroalgal biomass. Canopy species were less evenly distributed among bays (Table 23); N. integra was not found in Bay 9 and Laminaria spp. and F. distichus were much less abundant in Bays 7 and 9 than in Bays 10 or 11. Punctaria glaciale was not found in Bay 11 and Chorda spp. were collected there only in 1980.

Biomass

Mean biomasses of total algae and dominant species collected in airlift samples along transects at 3 m depth in each of the study bays and periods are shown in Table 23. Mean biomass of total macroalgae was from 134.1 to 936.7 g/m2, depending on bay and period. These values (based on formalin-preserved wet weight) probably underestimate fresh weight; Thomson and Cross (1980) reported a considerable (>30%) formalin-induced reduction in the

Table 23. Mean biomass of the 10 most abundant groups or species of macrophytic algae at 3 m depth in four bays[1] at Cape Hatt, northern Baffin Island, during September 1980 and August and September 1981[2]. Biomass expressed as mean * SD of 10% formal in preserved wet weight; n = 15-22 airlift samples (0.0625 m^2) per bay/period combination.

Species or Group[3]	Period	Bay 7	Bay 9	Bay 10	Bay 11
Stictyosiphon tortilis	1		53,15 * 50.34	185.16 ± 148.65	145.18 ± 132. S3
	2	63,08 ± 33.64	67.20 * 93.57	34.17 * 35.71	394.30 * 679.28
	3	45.38 * 38.67	55.71 * 84.31	37.62 * 43.28	629.31 * 1271.09
Pilayella littorals + d iatoms[4]	1		113.41 ± 42.82	154.74 * 139.57	119.85 * 151.90
	2	66.09 * 37.32	41.95 * 31.55	50.06 ± 44.38	102.95 * 143.66
	3	69.65 ± 61.13	55.17 * 26.12	46.94 * 55.31	211.18 ± 329.87
Dictyosiphlon foeniculaceus	1		64.47 ● 124.61	133.14 * 147.16	3.02 * 7.14
	2	2.88 * 2.72	23,21 ± 28.80	7.70 i 8.62	1.05 ± 1.96
	3	4.01 * 3.74	25.26 * 37.52	15.96 ± 22.39	0.26 ± 0.45
Need ilsea integra	1		0	34.02 ± 106.95	0.19 ± 0.50
	2	21.92 ± 49.15	0	67.88 ± 172.13	1.75 * 5.83
	3	15.92 ± 43.04	0	117.26 * 270.48	1.38 ± 3.47
Fucus distichus	1		0.71 * 1.16	9.71 * 19.62	46.03 ± 93.46
	2	9.80 ± 37.65	0.32 * 1.20	9.66 ± 41.58	15.40 ± 26.21
	3	0.52 ± 1.58	0.56 ± 1.08	17.66 ± 53.73	39.55 * 87.88
Laminaria spp.[5]	1		2.59 ± 11.86	6.48 ± 21.08	1.23 ± 3.34
	2	1.31 * 4.93	0.12 * 0.40	20.51 ± 38.36	8.60 * 26.16
	3	<0.01	0.02 * 0.08	62.67 * 129.92	9.24 * 14.85
Sphacelaria spp.[5]	1		1.24 ± 1.44	50.02 ± 74.14	15.60 ± 24.67
	2	1.23 * 1.20	0.58 * 0.62	16.51 * 17.79	6.15 ± 7.82
	3	0.86 * 0.83	0.82 ● 0.84	9.41 * 15.64	17.14 * 31.67
Chords spp. 5	1		34.34 ± 30.37	5.70 * 19.38	1.28 * 3.23
	2	0.14 * 0.31	0.02 * 0.05	0.03 * 0.10	0
	3	5.15 * 9.26	4.01 ± 5.07	0.21 * 0.70	0
Chaetomorpha spp.[5]	1		0.02 * 0.07	3.30 ● 6.70	4.63 ± 9.97
	2	0.09 * 0.15	0.02 * 0.05	1.57 ± 2.02	4.76 ± 3.76
	3	0.08 * 0.19	0.01 * 0.03	1.29 * 1.93	10.89 ± 9.88
Punctaria glaciale	1		0.52 ± 1.70	0	0
	2	2.76 ● 5.66	0.16 ± 0.47	0.08 ± 0.32	0
	3	12.69 * 17.78	1.32 ± 4.16	0.44 * 1.16	0
Total Algae[6]	1		278.17 ± 143.27	607.83 ± 492.16	355.40 * 340.13
	2	172.70 * 76.12	134.13 * 124.84	216.38 ● 209.59	560.39 * 806.68
	3	156.48 ± 107.56	145.69 ± 118.74	330.79 ± 324.83	936.72 ± 1501.36

[1] Bay 7 = reference; Bay 9 = heavy dispersed oil; Bay 10 = light dispersed oil; Bay 11 = surface oil spill.
[2] Period 1 = pre-spill, September 1980; Period 2 = pre-spill, August 1981; Period 3 = post-spill, September 1981.
3 Listed in order of overall abundance.
4 p. 1 ittoralis and tubular diatoms not separated.
5 Genera listed include species listed in Table 2[2].
6 Includes other species not weighed individually.

weight of under story algae from Cape Fanshawe, Bylot Island. Algal biomass at Cape Hatt (Table 23) was higher than the biomass of macroalgae other than kelp at most of the 5 and 10 m stations studied by Thomson and Cross (1980). However, kelp biomass in the Lancaster Sound area was considerably higher (0.5-12.7 kg/m2 fresh wet weight). The only estimates of kelp biomass at Cape Hatt were made on 3 m transects (Laminaria spp., Table 23); biomass would have been much higher in the narrow Laminaria zone that was observed at 4-5 m depth.

Results of analyses of variance (ANOVA) for log-transformed biomasses of total algae and dominant members of the understory community at 3 m are shown in Table 24. Differences among transects were significant for all variables except Pilayellalittoralis + diatoms (4 bay/2 period analysis only). Differences among bays after accounting for within-bay differences were also significant for most variables; only the biomass of P. littoralis + diatoms was similar in different bays (3 bay/3 period analysis only). Biomasses of Stictyosiphon tortilis (both analyses) and P. littoralis + diatoms (4 bay/2 period analysis only) were significantly higher in Bay 11, and similar (i.e. not statistically different) in the other 2 or 3 bays. Dictyosiphon foeniculaceus, on the other hand, was least abundant in Bays 7 and 11, and most abundant in Bays 9 and 10.

Temporal differences was not significant for any of the variables in the 4 bay/2 period analysis. Thus seasonal variation in 1981 (August-September) was not significant relative to small-scale (transect) spatial variability. Year-to-year differences, however, were significant for D. foeniculaceus and P. littorals + diatoms (3 bay/3 period test); in both cases biomass was higher in September 1980 than in August or September 1981.

Table 24. Three-factor analyses of variance (ANOVA) for the biomass[1] of macro phytic algae at 3 m depth in the study bays at Cape Hatt, northern Baffin Island, during September 1980 and August and September 1981. Transects are nested within bays. F-values are shown with significance levels (ns = P>0.05; * P≤0.05, ** P≤0.01, *** P≤0.001).

		Source of Variation and df[2]				
Analysis	Taxon	Per iod (2),16	Bay 2(3),16	Period x Bay[4] 4(3) ,16	Transect (Bay) 6,147 (8,126)	Per x Trans (Bay) 12,147 (8,126)
3 bay/3 period[3]	Total algae	3.34 ns	5.32 *	2.71 ns	3.69 **	1.21 ns
	Stictyosiphon tortilis	0.91 ns	12.09 ***	3.10 *	6.30 ***	1.35 ns
	Dictyosiphon foeniculaceus	8.81 **	14.61 *-	3.78 *	8.67 ***	1.52 ns
	Pilayella littoralis + diatoms	8.72 **	1.00 ns	2.88 ns	2.60 *	0.53 ns
4 bay/2 period[4]	Total algae	1.74 ns	8.29 **	0.63 ns	2.41 *	0.53 ns
	Stictyosiphon tortilis	0.02 ns	13.81 ***	0.42 ns	3.63 ***	1.01 ns
	Dictyosiphon foeniculaceus	1.20 ns	11.21 ***	0.51 ns	2.99 **	1.31 ns
	Pilayella littoralis + diatoms	2.52 ns	6.35 **	1.94 ns	1.08 ns	0.13 ns

1 Formalin-preserved wet weight; log-transformed.
2 df are shown for 3 bay/3 period analysis, followed by 4 bay/2 period analysis (in brackets).
3 Bays 9 (heavy dispersed oil), 10 (light dispersed oil) and 11 (surface oil spill); Periods 1 (pre-spill, September 1980), 2 (pre-spill, August 1981) and 3 (post-spill, September 1981).
4 Bays 7 (reference), 9, 10 and 11; Periods 2 and 3.

The possibility of an oil effect on two dominant members of the under story community, _S. tortilis_ and _D. foeniculaceus_, is indicated by the marginally significant bay x period interactions in the 3 bay/3 period analysis (Table 24). However, inspection of the data (Table 23), together with the marginal level of significance ($0.01<P<0.05$) of these results and the non-significance of the interaction effect in the 4 bay/2 period analysis (Table 24), lend little support to this hypothesis. The interaction effect consisted of a 1980-1981 decrease in Bay 10, a progressive increase from Period 1 to 3 in Bay 11, and little change in Bay 9 (Table 23). This pattern of changes is not consistent with the idea that the interaction effect represented an oil effect. Similarly, inconsistent temporal changes in _D. foeniculaceus_ do not appear to be related to the oil treatments (Table 23). Total algal biomass decreased slightly from August to September 1981 (pre- to post-spill) in the reference bay, and increased in the three treatment bays (Table 23), but these changes were not statistically significant and cannot be attributed to the effects of oil. Variability in macroalgal biomass was attributable primarily to small-and large-scale spatial variability, and in some cases to annual variability (1980 > 1981).

Substrate Cover

Mean percent of the substrate covered by macrophytic algae at 3 and 7 m depths in each bay and period, based on _in situ_ estimates within 10 m2 areas, are shown in Table 25. Separate estimates were made for total bottom cover (primarily the lower stratum of mixed filamentous and dendritic forms), and for larger foliose algae (_Fucus distichus_, _Neodilsea integra_ and _Palmaria palmata_). Percent cover was estimated directly in September 1980, but in

Table 25. Estimates of macrophyt ic algal percent cover and density based on in situ counts at 3 m and 7 m depths in the study bays[1] at Cape Hatt, northern Baffin Island, during September 1980 and August and September 1981[2]. Data are expressed ae mean ± SD and are baaed on five 1 x 10 m areas on three transects for each depth, period and bay.

Depth	Category	Period	Bay 7	Bay 9	Bay 10	Bay 11
3 m	Understory[3] (%)	1		82.0 * 14.0	41.0 ●24.0	59.0 * 33.0
		2	79.1 ± 12.8	43.0 ± 25.5	46.2 ± 24.7	62.0 ± 26.2
		3	45.1 ± 24.4	74.5 ± 11.6	89.1 * 9.5	62.8 ± 30.5
	Canopy[4] (%)	1		1.0 * 2.0	20.0 * 18.0	17.0 * 13.0
		2	19.6 * 16.6	0.8 * 1.4	18.3 ± 13.4	3.8 ± 2.4
		3	17.0 ●20.8	1.2 * 1.5	13.5 * 13.9	5,13 ± 3.3
	Laminariales[5] (no. /10 m²)					
	<30 cm	1				
		2	0	0	11.53 * 14.71	9.20 ± 1,55
		3	0	0	32.07 ± 31.71	9.00 * 3,13
	30-100 cm	I				
		2	0.07 ± 0.26	0	1.93 * 4.13	0.93 * 1,62
		3	0.13 ± 0.52	0	9.13 * 10.78	3.40 * 4.21
	>100 cm	1				
		2	0	0	0.87 * 3.09	0.53 ± 1.31
		3	0	0	4.60 ± 6.71	2.67 ± 4.35
7 m	Understory[3] (%)	1		5.0 ± 5.0	8.0 ± 5.0	19.0 * 22.0
		2	3.8* 3.1	5.0 * 5.3	27.9 * 15.7	28.4 ± 13.8
		3	6.2 ± 5.5	4.4 * 4.4	49.0 * 23.4	23.4●15.5
	Canopy[4] (%)	1				
		2	3.0 * 2.0	7.4 ± 8.1	4.4 ●4.4	1.0 * 1.5
		3	3.2 ± 0.8	1.0 ± 1.5	5.6 ± 1.1	3.6 i 4.1
	Laminariales[5] (no. /10 m²)					
	<30 cm	1				
		2	0.13 * 0.35	0	0.53 ± 0.74	0.13 ± 0.35
		3	0.07 ± 0.26	0.40 * 0.83	1.80 * 2.40	0.73 * 0.70
	30-100 cm	1				
		2	0	0.20 ± 0.56	1,07 * 1.58	0.80 ± 1.82
		3	0.13 ± 0.35	0.13 ± 0.52	2.27 * 2.69	0.60 * 0.91
	>100 cm	1			1.4 * 1.0	1.2 * 1.1
		2	0	0	1.00 * 2.07	0.73 ●0.96
		3	0.07 ± 0.26	0.07 ± 0.26	1.40 ± 1.64	0.80 ± 1.86

1 Bay 7 = reference; Bay 9 = heavy dispersed oil; Bay 10 = light dispersed oil; Bay 11 = surface oil spill.
2 period 1 = pre-spill, September 1980; Period 2 = pre-spill, August 1981; Period 3 = post-spill, September 1981.
3 Primarily *Stictyosiphon foeniculaceus*, *Dictyosiphon tortilis*, *Pilayella littorals* and tubular diatoms.
4 Primarily *Neodilsea integra* and *Fucus distichus*.
5 *Laminaria* spp. and *Agarum cribrosum*.

August and September 1981 cover was estimated as being one of the following percent cover classes: O, 1-5, 5-25, 25-50, 50-75, 75-95, 95-99, 100. In 1981, counts were made for different size classes of Laminaria spp. and Agarum cribrosum (<30 cm, 30-100 cm, >100 cm), whereas in 1980 only large kelp were counted. Hence caution should be exercised in comparing 1980 and 1981 data.

Substrate cover by the understory algal community was high and relatively even at 3 m depth. Between Periods 2 and 3, percent cover decreased in Bay 7, increased in Bays 9 and 10, and was constant in Bay 11. At 7 m the understory covered a smaller proportion of the bottom. Pert ent cover was highest in Bays 10 and 11 during Periods 2 and 3 (from 23.4 to 49.0%), and in all other cases was from 3.8 to 19.0%. Marked changes between Periods 2 and 3 occurred only in Bays 7 and 11 where substrate cover increased. There is little correspondence between these data from 3 m depth and the biomass data in Table 23, probably because the understory community is , for the most part, loose-lying. Changes in percent cover could result either from growth or from redistribution due to water movement.

Canopy algae, including long-bladed kelp and short foliose species, covered a small percentage of the substrate at both depths, and were unevenly distributed among bays at 3 m depth. The only substantial change from Period 2 to 3 at either depth was a decrease in cover at 7 m in Bay 9 (Table 25). Better correspondence exists between percent cover and biomass data for canopy species at 3 m depth than for understory species In most cases these species are attached to gravel or shell, although in Bay 11 most of the Fucus distichus collected was loose-lying.

The kelp at Cape Hatt consisted primarily of Laminaria saccharin and, to a lesser extent, Agarum cribrosum. Few kelp occurred in Bays 7 or 9 at either depth. Highest densities occurred at 3 m in Bays 10 and 11; small plants were most abundant and large plants were least abundant in both bays. At 7 m depth size classes were of similar abundance, and kelp densities were similar between Bays 10 and 11. At 3 m depth, marked increases in density occurred between Periods 2 and 3 for all size classes in Bay 10 and for the two larger size classes in Bay 11. At 7 m depth, increases occurred only in the smaller size classes (Table 23). Increases in densities of small (<30 cm) plants resulted largely from recruitment and growth of sporophytes; most small plants in Bay 10 at 3 m during Period 3 were 2 to 15 cm in length.

Surveys were conducted within the same areas in each bay and period, and increases in density of the larger size classes of kelp must have resulted from growth from one class to the next. Summer growth rates of Laminaria solidungula at Igloolik, Foxe Basin (Chapman and Lindley 1980), and of Laminaria groenlandica at Auke Bay, Alaska (Calvin and Ellis 1981), seem too low (approximately 1 mm/day) to support this hypothesis. Johnston et al. (1977), however, reported that Laminaria saccharin in Scotland produced 23 cm of new growth during August, and a minimum monthly growth of 8 cm in November. These differences are attributable both to environmental factors (temperature, nutrient and light levels) and to differences among species; a faster growth rate in terms of length would be expected for L. saccharin because its blades are much narrower than those of L. solidungula or L. groenlandica.

Oil at concentrations between 3 and 147 ppm has been reported to inhibit photosynthesis in L. saccharin (Shiels et al. 1973; Hsiao et al. 1978). Any reduction in photosynthesis that may have resulted from either spill at Cape Hatt was not of sufficient magnitude to stop kelp growth in Bays 10 or 11. It is not possible to determine the magnitude of effects on density or growth, however, because of the absence or low densities of kelp in Bays 7 (reference) and 9 (highest level of dispersed oil) in both pre- and post-spill periods.

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APPENDIX 1. Dates and locations (depth, bay, transect, and number of metres frcm N to S along the transect line) of each airlift sample collected at Cape Hatt in 1980 (Period 1) and 1981 (Perioda 2 and 3).

Depth	Bay	Transect	Period	Replicate 1	2	3	4	5	6	7	8	Date(s)
7m	7	1	2	2	6*	24	29	31*	36	39*	45	16 Aug
			3	1*	4	11*	15	24*	33*	40*	42	3 Sept
		2	2	0	19	30	31*	35	37	38*	49*	16 Aug
			3	4*	10*	12*	26	28	36	46	48*	3 Sept
		3	2	5*	9	11*	15	20	22	27	36*	17 Aug
			3	0	5	14	17*	25	25*	29*	48	3 Sept
	9	1	1	2	8*	20*	23*	31	35	36	43	1 Sept
			2	13	14	14*	18*	33	36	45*	48*	6 Aug
			3	10*	16	20	24*	27*	37*	38	45	5 Sept
		2	1	6	24*	25	32*	37	43*	43	48	31 Aug, 1 Sept
			2	2*	8*	10	18*	27*	41	44	49	6, 7 Aug
			3	3*	7	10*	12*	24	26	26*	42*	5 Sept
		3	1	2	8*	20*	23*	31	35*	36*	43	31 Aug
			2	5*	10*	13*	14	17	20	34*	42	7 Aug
			3	2*	7	18	19	25*	45*	46	47	5 Sept
	10	1	1	1	2*	7*	13*	14	16	29*	31	3 Sept
			2	6	9*	15	27	30	33	41*	48	13 Aug
			3	19*	26	33*	39	40*	42	48*	50	6 Sept
		2	1	5*	8	11	16*	20*	24	33*	41*	3 Sept
			2	4	10	13*	22	25	27	32	39*	13 Aug
			3	5	15	15*	22*	24*	25*	26*	30*	6 Sept
		3	1	5	9*	16*	20	24*	25	38*	44	3 Sept
			2	3	4*	10*	13*	31	39	45	48*	14 Aug
			3	1	2*	10	18	24	39*	41*	43	6 Sept
	11	1	1	1	5*	12*	23*	24	33	39*	40*	4, 5 Sept
			2	3	8	8*	12*	29*	35*	35*	39*	10 Aug
			3	15	19	25	26	27*	30*	38*	42	1 Sept
		2	1	6	12*	14*	16*	27*	29	40*	41	5, 6sept
			2	3*	6*	14	35	40	45	47*	48	12 Aug
			3	3	3*	13*	18*	20	22*	30*	47*	1, 2 Sept
		3	1	4*	20	25*	27	28	40	43*	45*	6 Sept
			2	4	6*	8*	14*	34*	35	36	48*	12 Aug
			3	6	8	11	12*	13*	28	30	44	2 Sept

Continual...

APPENDIX 1 Cent inued.

Depth	Bay	Transect	Period	Replicate 1	2	3	4	5	6	7	8	Date(s)
3m	7	1	2	12	15*	24	27	33*	36	44	45	17 Aug
			3	8	9	20	26*	34	39	39*	48*	5 Sept
		2	2	11	11*	16*	20	26	27	41	44	17 Aug
			3	2*	3	6*	7*	33	36	37	49*	5 Sept
		3	2	9	15*	17*	19	38	38*	39*	40*	17 Aug
			3	2*	3	8*	10	16	20	27*	42*	5 Sept
3m	9	1	1	2*	5	10	11*	14	20	33	39*	10 Sept
			2	1	3	9	17	18*	23	32	39	7 Aug
			3	4*	21	24*	29	32*	35*	43	49	6 Sept
		2	1	1*	9	10	17	24*	30	36	44	10 Sept
			2	7*	17*	23	24	32	38	45*	46	7, 8 Aug
			3	14*	19	31*	38*	39	39*	40*	44	6 Sept
		3	1	6*	16*	21	27	30*	33	38	45	10 Sept
			2	2*	5	8	12	15	45	45	48	7, 8 Aug
			3	3*	8*	14	20*	23	40*	46	47	6 Sept
	10	1	1	4*	11	30	33*	37*	43 .	45	46*	7 Sept
			2	1	5	12	13*	33	39*	42*	45*	14 Aug
			3	0	7	14*	16*	17*	33*	34*	46	7 Sept
		2	1	3*	6*	11	13	17*	32*	44	46	7 Sept
			2	2*	9*	10*	12*	13*	21*	24*	27*	14 Aug
			3	3	4	11*	14	15	22*	34	37	7 Sept
		3	1	2*	5*	8	13*	14	30	31	37*	8 Sept
			2	10	18*	20*	25	39	42	43	46	14 Aug
			3	3	15	16*	24*	25*	27	38	41*	7 Sept
	11	1	1	0*	6*	12	16*	21	41	44	45*	9 Sept
			2	4	4*	8	11	18	20*	22*	33	12 Aug
			3	6	15	23*	26	27*	36	37	42	2 Sept
		2	1	1*	12*	19*	26	27	30	39*	47	9 Sept
			2	17	18	22	29*	31	32	33	40	12 Aug
			3	10	25	30*	31*	37*	40	47*	48*	2 Sept
		3	1	0	1*	6	7	14*	16*	18	42*	9 Sept
			2	1	9*	11*	25	26	30*	31	32	12 ALlg
			3	4	8	13*	17	19	23	35	39*	2 Sept

* Indicates sample taken seaward of transect line.

APPENDIX 2. List of species of benthic fauna collected by airlift at Cape Hatt, northern Baffin Island, during August 1980 and August and September 1981.

ANTHOZOA

Unidentified Anthozoa

NEMERTINEA

Unidentified Nemertinea

NEMATODA

Unidentified Nematoda

POLYCHAETA

Ampharete arctia
A. actuifrons
Amphicteis sundevalli
Amphitrite cirrata
Anaitides groenlandica
Antinoella sarsi
Aphroditidae spp.
Aricidea spp.
Asabellides sibrica
Axiothella catenata
Brada granulata
Capitella capitata
Chaetozone setosa
Chone infundibuliformis
Cirratulidae spp.
Cistenides granulata
C. hyperborea
Diplocirrus hirsutus
Dysponetus pygmaeus
Ephesiella minuta
Eteone flava
E. longa
E. spitzbergensis
Euchone analis
Exogone verrugera
Gattyana cirrhosa
Glycera capitata
Harmothoe extunuata
H. imbricata
Lanassa venusta
Laonome kroeyeri
Lumbrineris minuta
Maldane sarsi
Maldanidae spp.
Mediomastus sp.
Melaenis loveni
Myriochele oculata
Nephtys ciliata
Nephtys sp.
Nereimyra punctata
Nereis zonata
Nicolea sp.
Nicomache lumbricalis
Ophelia limacina
Opheliidae spp.
Ophelina aulogaster
Owenia fusiformis
Oweniidae spp.
Petaloproctus tenuis
Pholoe minuta
Phyllodoce groenlandica
Pista cristata

Continued. . .

APPENDIX 2 Cont.

P. maculata
Polydora quadrilorata
Praxillella praetermissa
Praxillella sp.
Prionospio steenstrupi
Pygospio elegans
Sabellidae spp.
Scoloplos armiger
Spio filicornis
Spio sp.
Spionidae spp.
Spirorbis sp.
Terebellides stroemi
Tharyx marioni
Travesa forbesi
Trichobranchus glacialis

GASTROPODA

Acmaea rubella
Acmaea testudinalis
Admete couthouyi
Alvania mighelsi
Alvania sp.
Beringius sp.
Buccinum ciliatum
B. cf. scalariforme
B. sericatum
B. undatum
Buccinum sp.
Cingula castanea
Colus islandicus
C. roseus
C. cf. spitzbergensis
C. togatus
C. tortuosus
Frigidoalvania cruenta
Lunatia pallida
Margaritas helicinus
M. umbilicals
Moelleria costulata
Natica clausa
Oenopota cf. bicarinata
O. incisula
O. pyramidalis
O. reticulate
Oenopota sp.
Onoba aculeus
Philine obtusa
Propebela turricula
Retusa abtusa
Scaphander punctostriatus
Trichotropis borealis
Unidentified Gastropoda

POLYPLACOPHORA

Tonicella marmorea

BIVALVIA

Astarte borealis
A. montagui
Clinocardium ciliatum
Hiatella arctica
Macoma calcarea
M. moesta
Musculus discors substriatus
M. niger

Continued. . .

APPENDIX 2 Cont.

Mya truncata

Mytilus edulis

Nucula belloti

Nuculana minuta

Serripes groenlandicus

Thracia sp.

Thyasiridae spp.

Yoldiella sp.

CUMACEA

Brachydiastylis resima

Campylaspis rubicunda

Diastylis rathkei

D. sculpts

Eudorella sp.

Lamprops fuscata

Leptostylis sp.

Leucon nasicoides

Leucon sp.

OSTRACODA

Eucytheridea bradii

E. punctillata

Finmarchinella finmarchica

Philomedes globosa

Rabilimis mirabilis

AMPHIPODA

Ampelisca eschrichti

Anonyx laticoxae

A. lilljeborgi

A. nugax

A. sarsi

Atylus carinatus

Bathymedon longimanus

B. obtusifrons

Boeckosimus edwardsi

B. plautus

Byblis gaimardi

Calliopiidae spp.

Centromedon sp.

Corophium clarencense

Gammaracanthus loricatus

Gammarus setosus

G. wilkitzkii

Guernea sp.

Haploops tubicola

Harpinia serrata

Ischyrocerus sp.

Lysianassidae spp.

Melita dentata

Monoculodes borealis

M. latimanus

M. longirostris

M. schneideri

Monoculopsis longicornis

Oediceros borealis

Onisimus litoralis

Opisa eschrichti

Orchomene minuta

Paramphithoe sp.

Paroediceros lynceus

Phoxocephalus holboli

Pleustidae spp.

Pontogenia inermis

Pontoporeia femorata

Continued. . .

APPENDIX 2 Concl.

Protomedia fasciata
Stenothoidae spp.
Westwoodilla megalops
Westwoodilla sp.
Weyprechtia pinguis

DECOPODA

Argis sp.
Lebbeus polaris
Pasiphaeidae spp.
Sabinea sarsii
Sclerocrangon boreas
S. ferox
Spirontocaris phippsi

OTHER CRUSTACEA

Unidentified Mysidacea
Unidentified Nebaliacea
Unidentified Tanaidacea
Unidentified Isopoda

ASTEROIDEA

Leptasterias groenlandica
L. polaris
Stephanasterias albula

OPHIUROIDEA

Amphiura sundevalli
Ophiocten sericeum
Ophiopus arcticus
Ophiura robusta
Ophiura sarsi

ECHINOIDEA

Strongylocentrotus droebachiensis

HOLOTHUROIDEA

Myriotrochus rinkii

ASCIDIACEA

Rhizomolgula globularis
Unidentified Ascidiacea

OTHER PHYLA

Echiura sp.
Priapulus bicaudatus
P. caudatus
Unidentified Sipuncula

PISCES

Artediellis uncinatus
Eumicrotremus sp.
Gymnelis viridis
Gymnocanthus tricuspis
Myxocephalus scorpius
Myxocephalus sp.

APPENDIX 3. Mean density * SD of the 21 most common species found at the 3 m depth in all bays and sampling periods. Also shown are the correlations between the log transformed densities of each of these 21 species and each of the 6 factors determined in a factor analysis that only considered the 262 samples taken at the 3 m depth.

Taxon	Density ($no./m^2$) Mean * SD	Correlation Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Nemertean sp. A.	46.5* 61.0	-0.048	-0.094	-0.022	0.071	0.065	0.842
Pholoe minuta	381.6 *383.9	0.468	0.023	0.237	0.574	0.043	0.016
Euchone analis	172.6* 253.2	0.393	-0.312	0.522	0.334	0.086	0.153
Nereimyra punctata	289.5 ± 289.8	-0.074	0.716	0.157	0.020	0.361	0.055
Eteone longa	89.5 ± 105.7	-0.107	0.206	-0.346	0.343	0.570	0.164
Capitella capitata	30.6 * 64.3	-0.092	-0.240	0.074	-0.226	0.770	-0.011
Harmothoe imbricata	40.5 * 53.3	-0.158	0.627	-0.147	0.167	-0.176	-0.062
Cistenides granulata	18.3 ± 24.0	0.511	0.183	0.052	0.275	-0.112	-0.096
Scoloplos armiger	15.4* 19.6	0.480	-0.000	0.202	-0.082	-0.102	0.429
Mya truncata	134.3 * 149.1	9.487	0.064	0.551	0.393	-0.036	0.016
Thyasiridae spp.	94.2 * 169.0	0.673	-0.052	0.474	0.080	0.101	0.030
Astarte borealis	116.1 * 168.3	0.803	-0.015	0.016	0.091	0.014	0.088
Astarte montagui	70.0* 160.0	0.750	-0.215	0.062	0.142	-0.263	-0.025
Astarte juveniles	35.8 ± 77.4	0.105	0.024	0.767	0.054	-0.084	-0.041
Musculus discors	50.7 * 109.0	0.011	0.782	-0.019	-0.185	-0.014	-0.010
Musculus juveniles	33.3 * 75.6	-0.044	0.699	-0.009	-0.052	-0.125	-0.071
Myriotrochus rinkii	161.8 ± 151.3	0.277	0.058	0.046	0.671	-0.281	0.206
Cingula castanea	129.8 * 210.8	0.658	-0.174	0.286	0.179	0.135	-0.013
Trichotropis borealis	28.9 * 91.3	0.672	-0.351	0.007	0.222	-0.308	0.018
Retusa obtusa	37.6 *47.1	0.183	-0.334	0.236	0.668	0.062	-0.048
Cirratulidae spp.	95.3 * 136.3	0.085	0.016	0.552	0.164	0.063	0.456

APPENDIX 4. Mean density ± SD of the 27 most common species found at the 7 m depth in all bays and sampling periods. Also shown are the correlations between the log transformed densities of each of these 27 species and each of the 9 factors determined in a factor analysis that only considered the 262 samples taken at the 7 m depth.

	Density (no./m²)	Correlation								
	Mean ± SD	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9
Pholoe minuta	362.9 * 221.9	0.414	-0.043	0.179	0.059	-0.109	0.360	-0.169	0.452	0.041
Nereimyra punctata	22.8 ± 62.2	Owl	-0.241	-0.180	-0.094	-0.200	0.391	-0.409	0.279	0.207
Eteone longs	19.7 * 24.5	-0.328	-0.038	-0.071	-0.193	0.046	0.132	-0.008	-0.080	0.624
Capitella capitata	14.4 • 27.0	0.029	0.039	-0.014	0.118	0.038	0.015	-0.0$4	0.149	0.762
Harmothoe imbricata	22.8 ± 32.8	0.017	-0.235	-0.143	0.157	-0.423	0.223	0. 106	o.4n	-0.116
Cistenides granulata	60.2 ± 41.3	-0.018	-0.038	0.033	-0.037	0.117	0.823	0.134	-0.029	0.0%
Scoloplos armiger	29.2 ± 27.7	0.311	0.120	-0.019	-0.616	0.035	0.130	0.042	0.174	-0.014
Praxillella praetermissa	35.1 * 33.2	-0.009	0.628	0.175	-0.198	0.113	-0.200	0.033	0.130	0.044
Maldane sarsi	41.1 * 72.5	0.039	0.448	-0.271	0.555	-0.066	-0. 139	-0.061	-0.089	0.016
Aricidea sp.	24.0 * 31.2	-0.016	-0.023	0.043	-0.181	0.098	-0.133	0.038	0.789	0.134
Mya truncata	126.7 * 86.2	0.10$	0.495	0.205	-0.062	0. 190	-0.108	0.4%	0.076	0.0$3
Thyasiridae spp.	3%.0 * 275.4	0.831	0.046	0.015	-0.164	-0.129	0.0$5	-0.142	-0.023	-0.042
Astarte borealis	327.3 * 204.9	0.253	0.757	-0.017	0.048	-0.122	0.159	0.082	-0.108	-0.099
Astarte montagui	223.0 ± 227.2	-0.123	0.757	-0.044	0.095	-0.026	0.026	0.151	-0.162	0.071
Astarte juveniles	71.63 ± 123.0	-0.033	0.1%	0.019	0.003	-0.017	0.142	0.772	0.044	-0.045
Macoma calcarea	133.3 * 99.1	0.661	0.029	0. 188	-0.(I36	0.158	-0.016	-0.002	0.018	-0.156
Macoma moesta	63.5 ± 63.5	0.433	-0.069	0.202	-0.014	0.149	-0.368	0.154	0. 100	-0.181
Macoma juveniles	44.7 * 50.5	0.529	0.063	0.115	0.076	-0.003	0.020	0.356	0.049	0.359
Serripes groenlandicus	33.0 ± 37.3	0.388	-0.051	0.526	-0.2%	0.054	-0.037	0.039	-0.167	0.057
Musculus niger	31.8 ± 50.3	0.311	0.192	0.577	-0.064	0.009	-0.138	0.189	-0.021	-0.002
Nuculana minuta	82.1 ± 57.1	0.443	0.360	0.212	0.299	0.030	-0.0%	0.100	0.047	-43.147
Myriotrochus rinkii	24.1 ± 56.9	0.021	-0.042	0.617	0.010	-0. 328	0.078	0.210	0.237	-0.148
Moelleria costulata	19.1 ± 27.0	0.0%	-0.030	0.111	0.614	0.347	0.222	0.099	0.066	-0.005
Cingula castanea	46.2 ± 60.5	0.341	-0.079	0.587	0.335	-0.014	-0.064	-0.027	-0.122	0.114
Trichotropis borealis	51.0 * 50.9	-0.087	0.168	0.256	0.231	0.5%	0.217	0.185	-0.073	-0.022
Retusa obtusa	20.9 ± 28.8	-0.042	0.260	0.586	0.039	0.201	0.173	-0.346	0.142	-0.149
Diplocirrus spp.	21.4 ± 28.4	0.093	-0.117	-0.205	0.017	0.721	-0.024	-0.024	0.068	0.052